HERMANN VON SCHRENK

PROCEEDINGS

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THIRTY-FIFTH ANNUAL CONVENTION

OF THE

American Railway Engineering Association

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BUSINESS SESSION

PROCEEDINGS

The object of this Association is the advancement of knowledge pertaining to the scientific and economic location, construction and maintenance of Railways. Its action is not binding upon its members.

TUESDAY, MARCH 13, 1934

MORNING SESSION

The Thirty-fifth Annual Convention of the American Railway Engineering Association was called to order in the Grand Ball Room of the Palmer House, Chicago, by the President, Mr. W. P. Wiltsee, Chief Engineer, Norfolk & Western Railway.

The President:—The meeting will please come to order. I will ask that the Board of Direction please come to the platform.

Thirty-five years ago a great and powerful organization was started, the main object of which was research as applied to the railroads. At that time there were very few such organizations, I am told not more than those you could count on the fingers of your hands, but now the number has increased to over 1500 in this country.

This meeting is also the annual session of the Construction and Maintenance Section of the American Railway Association, Division IV—Engineering, the meetings being concurrent.

The first order of business is the reading of the Minutes of the last annual meeting. Inasmuch as these Minutes have been printed and a copy furnished each member, the reading of the Minutes will be dispensed with, unless there is objection. I hear no objection; therefore the Minutes stand approved as printed.

ADDRESS OF PRESIDENT W. P. WILTSEE

General

At the time our Association was organized (more than thirty-five years ago), there existed very little uniformity in methods or devices used in construction and maintenance of way work, even under similar climatic and physical conditions.

The men who gathered together at the primary meeting on October 21, 1898, saw the necessity for an organization such as ours. One reason for its formation was to give an opportunity for discussion among its members and an interchange of views on matters which were of common interest. The field was broad and the subjects many, so since that time the work has been of great benefit, not only to ourselves but to our employers. These men probably had in mind that the first work to be done was to investigate and report on the fundamentals of railway engineering, but as the object of our Association, stated in the Constitution adopted at the Organization Meeting on March 30, 1899, is "the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways", they had some vision of the present situation and the development of the art.

Research

The fundamental work was completed many years ago and we have been engaged for years in research work of a high degree and the application of its results to our engineering problems. The term "Research", as I understand it, covers a wide and varied

field of endeavor in the search for knowledge. Between the acquirement of knowledge in the technical research work of the scientist and the observations made by the field engineer to substantiate this knowledge from performance there is a distinct connection; one is not complete without the other. The facts and laws discovered in the laboratory are of value only as they may be applied in the advancement of the art to the end that we may obtain more economic uses of materials and devices in the construction and maintenance of our railroads. Therefore, the laboratory research work, without the support of field observation, is of little profit.

To assist our Committees in experimental and laboratory research, arrangements have been made to establish a Director of Research and staff, functioning directly under a special Research Committee, to work with and direct experiments and other scientific research work that may be required by our Standing Committees.

A Committee on Railroads of the Science Advisory Board, composed of twelve outstanding men in industry, commerce and education, was formed at the suggestion of the Federal Coordinator to cooperate with a Committee of six Railway Executives in a survey of the research facilities and procedures now existing in the railroad and equipment organizations, and determine whether the principles of scientific research are being applied in the railroad industry as thoroughly and effectively as practicable.

Publications

Publications have been issued as in the past. No new Manual has been printed, but the additions to the Manual were published in Bulletin form, as customary. The value of our work, as recorded in our Manual of Recommended Practices, is shown by the action of the railroads in putting these practices more and more into use. During the past year a plan has been put into effect, with a view to increasing the use of our Recommended Practices, by which questionnaires on several recommendations of the Association have been sent to the Railway Executives to determine whether they are now using or will use them as standard.

Finances

It is very gratifying to state that the Association is in sound financial condition. The operations during the calendar year show a substantial excess of receipts over disbursements. (The excess of receipts over disbursements was $3,964.99.)

Membership

It is to be deeply regretted that it is necessary to report a decrease in the number of members on the rolls. This situation is due to the economic conditions prevailing for the past four years. Reductions in forces, consolidation of positions, and so forth, have made it imperative, in many cases, for members affected to withdraw their affiliation in order to conserve their resources. It is hoped that with improvement in business the ground lost in this respect will be more than recovered, and that many former members will renew their membership.

In the current Bulletin the members will find a blank application for membership. It is urged that members detach this form and hand it to some eligible prospective member.

Deceased Members

During the year the Association has sustained the loss by death of a number of valued members, among them being Charles S. Churchill, Charter Member and Past-

President; M. L. Byers, Charter Member; Sir Henry W. Thornton; B. E. Holloway; G. E. Tebbetts; W. A. Christian and J. H. Gibboney, who was Chairman of our Arrangements Committee this year.

Committee Reports

The reports prepared by the several committees to be submitted for action at this Annual Meeting, compare favorably, both in quality and volume, with those offered in any preceding year. Committees have labored earnestly and painstakingly to prepare reports of outstanding value. Chairmen and members of Committees are to be complimented on their good work, and they have our grateful appreciation.

The thirty Standing and Special Committees are constantly engaged in research, not only that obtained through experiments of their own and other scientific bodies, but in service tests and summarizing the accumulated experience and records of all the railroads of the country.

The work originally contemplated by the Committee on Stresses in Railroad Track is now coming to a close, and this Committee has produced information that will be very valuable in its application to the design of our track structures. This Committee should be continued and the work extended.

During the past year the Committee on Rail Investigations has presented information that is worth a great deal to the railroads, in that their experiments have shown at least one cause to which transverse fissures in rails can be traced, and how they develop in track under heavy wheel loads.

Amendment to Constitution

At the request of the required number of members, an amendment to the Constitution was submitted to letter-ballot of the membership and adopted. The amendment related to the manner of placing the names of candidates for offices on the ballot. The Constitution now requires that where there is more than one candidate for any office, the names of candidates shall be placed in alphabetical order on the ballot. The proposed amendment provides that the order in which names are to be placed on the ballot shall be determined by lot by the Nominating Committee.

Honorary Membership

During the past year, the Board of Direction has conferred Honorary Membership on two highly respected and valued members: Past-President George Watson Kittredge and Doctor Arthur Newell Talbot, in recognition of distinguished services rendered the Association. Mr. Kittredge was the second President, and successfully piloted the Association during its formative period. Dr. Talbot's outstanding work as Chairman of the Committee on Stresses in Railroad Track and his valuable contributions to other activities of the Association amply warrant this honor.

Cooperative Activities

Contact has been maintained with other organizations on matters of mutual interest. Among such organizations are the following:

American Standards Association
American Society for Testing Materials
Portland Cement Association
University of Illinois
National Crushed Stone Association
Manganese Track Society

National Scale Men's Association
National Board of Fire Underwriters
Railway Fire Protection Association
American Transit Association
American Society of Municipal Engineers
American Petroleum Institute
Chemical Welfare Service, U.S. Army,

in addition to the several Divisions and Sections of the American Railway Association.

Special Committee on "Complete Roadway and Track Structure"

A new Special Committee has been authorized by the Board of Direction, entitled, "Complete Roadway and Track Structure", with instructions to study and report on "Complete roadway and track for various loads and traffic densities".

Revision of Portfolio of Trackwork Plans

Numerous changes and additions to the trackwork plans in recent years have made it necessary to reprint the portfolio and bring the volume up to date. The Track Committee has accordingly given this matter intensive study during the year and will submit a complete revision for approval at this Convention. The revised portfolio will be made available to the members as soon as practicable after the Annual Meeting.

Scales Used in Railway Service

It may be of interest to note that the "Specifications for the Manufacture and Installation of Motor Truck, Built-in, Self-Contained and Portable Scales for Railway Service", formulated by the Committee on Yards and Terminals, and shown on pages 447 to 462, inclusive, of Bulletin 361, have been printed as formal specifications for the City of New York. The reference is "New York City Specification 40–S–52".

Cooperation With Section of Purchases

The staff of the Federal Coordinator, through its Section of Purchases, has indicated its intention to make use of existing specifications for materials used by railways where such exist, rather than create standards of its own. Therefore, the American Railway Engineering Association has been urged to review such specifications with a view to making them available as standards for railway use. The Committees concerned are now giving these requests prompt attention. A survey has been made at the request of that Staff to ascertain the extent of use of the American Railway Engineering Association specifications, especially those involving materials. The results of this survey have been reported to the Director of Purchases.

Statement by the Federal Coordinator

Mr. Joseph B. Eastman, Federal Coordinator of Transportation, on October 6, 1933, transmitted a statement to the several Regional Coordinating Committees, with respect to the standardization of lumber, rail sections, rail joints and other accessories, in addition to a number of subjects pertaining particularly to the Mechanical Division and other Divisions of the American Railway Association.

The respective Committees of the American Railway Engineering Association were instructed to give preferred attention to these several matters. The present status of the items quoted above is as follows:

Standardization of Lumber

The Recommended Practices for Lumber and Timber now in the Manual, have been reviewed carefully by a Special Committee, composed of those experienced in the manufacture and purchase of lumber. The result of their study is to the effect that they are in conformity with the American Lumber Standards, although more work should be done to make them more readily usable by the purchaser; and that there is no lack of harmony between the Recommended Practices of the Engineering Division and the Mechanical Division of the American Railway Association.

Rail Sections

At the 1933 Convention, a section weighing 131 pounds per yard was adopted, superseding the 120, 130 and 140-pound RE Rail Sections. In July, 1933, a section weighing 112 pounds per yard was submitted to letter-ballot and adopted; this section to supersede the present 110-pound RE Rail Section. The 90 and 101-pound Rail Sections, now in the Manual, will not be changed.

Rail Joints and Other Accessories

A Joint Bar and Assembly for 112-pound rail was submitted to letter-ballot on January 20, 1934 and adopted. A Joint Bar and Assembly for 131-pound rail will be submitted to this Convention for adoption. Plans of Tie Plates have been submitted by the Track Committee, and are also offered for adoption at this Convention.

Recommendations

This is the thirty-fifth annual assembly of your Association. You may well feel a pardonable pride and satisfaction in its records of fulfillment from year to year, which achievement warrants the hope and expectation that the progress in future will measure fully up to the high standards of the past. In order to assist in accomplishing this, I have a few recommendations to offer:

1. Careful examination of the Manual and immediate steps to be taken to bring the subject-matter up to date.

2. That our Committee eliminate men who are not taking an active interest in the work, and thus tend to produce more active standing committees.

3. Amend our General Rules for the Preparation, Publication and Consideration of Committee Reports to require approval by letter-ballot on items that are adopted as Recommended Practice by the Convention, before printing in the Manual. This will give added importance to these items, and tend, not only to increase the standard of our work, but to extend their use as standard by the carriers.

4. That the Chairman of each Committee cooperate more fully with the other Divisions of the American Railway Association on any subject under consideration in which these other Divisions have an interest.

In Conclusion, I wish to thank all those who have been associated with me during my term in this office, and those who have so successfully carried on its committee-work; the members of the Board of Direction who have assisted me very much in many ways by their advice and recommendations, and especially in granting me unusual authority in handling matters that have arisen from time to time during the past year that were different from any of our past experiences and which required prompt decisions; the Chairmen and members of the Committees who have devoted their time to making this year a success; and, particularly, to the Committee on Outline of Work, which has had

a very difficult task during the past year in assigning the subjects in such a way as to avoid unnecessary time being spent on subjects of little, if any, value, and in avoiding duplication of work.

Our able Secretary who has completed thirty-five years of loyal and efficient service, I thank for the way he has handled the duties of his office, thus contributing very much to the pleasure of your President in serving you this past year (Applause).

The next order of business is the report of the Secretary and Treasurer.

(Secretary Fritch abstracted the reports of the Secretary and of the Treasurer.)

REPORT OF THE SECRETARY

March 1, 1934.

To the Members:

The thirty-fifth annual report on the general affairs of the American Railway Engineering Association is respectfully submitted herewith.

The past twelve months have been an unusually active period, especially in committee-work, which is the foundation of the organization's activities. From even a cursory or superficial inspection of the twenty-eight reports which are presented for approval and action at this convention, it will be apparent that a prodigious amount of work has been accomplished during the year.

Following the enactment of the Transportation Act of 1933, and the setting up of the staff of the Federal Coordinator of Transportation, instructions were received to cooperate with these Government agencies to the fullest extent. Your Association, through its committees, has whole-heartedly carried out those instructions. Contact was at once established with the Section of Purchases of the Coordinator's staff. It was gratifying to be assured from those in responsible charge of the Government's organization that they proposed to recognize the AREA recommended practices wherever applicable rather than set up standards of their own, and that they intended to promote and extend the use of such recommended practices wherever practicable.

The primary concern of the Government body was to promote those standards involving the greatest expenditure, for the ultimate purpose of increasing employment. A survey of the entire field was made and the most conspicuous examples selected for standardization. These included, first, rail and the necessary fastenings. It was intimated that rail sections should preferably be reduced in number to not more than five, preferably four. The Association, at its last annual meeting, had already adopted a rail section weighing 131-lb., this section to supersede the former 120-lb., 130-lb., and 140-lb. RE sections. The Committee on Rail was accordingly instructed to give this item preferred attention. A section weighing 112-lb. per yard was designed, and on account of the urgency of the matter, the new design was submitted to letter-ballot on July 1, 1933, and approved by a large majority of the members voting.

The Association had not heretofore designed joint-bars, and in line with instructions, gave intensive study to preparing plans for these devices for the several rail sections. A joint-bar and assembly for the 112-lb. rail section was formulated and submitted to letter-ballot on January 20, 1934. This was also adopted by a majority of the members voting. A joint-bar for the 131-lb. RE section will be submitted in a supplemental report by the Committee on Rail.

The subject of standard plans for tie plates was assigned to the Committee on Track on September 21, 1933. Work on this assignment was undertaken immediately, and as a result of its studies, the Committee formulated plans for 10-in., 11-in., 12-in. and 14-in. tie plates, which are being submitted for approval at this convention.

Plans and specifications for various track tools have been prepared during the year and are offered for approval as recommended practice.

Other items of trackwork and specifications therefor are under active consideration and will be reported out as rapidly as conditions warrant.

One of the features that is of interest is the requirement of the Coordinator's staff that manufacturers of devices used in the railway field be consulted in the preparation of standards. Committees of the AREA have invited the cooperation of manufacturers on subjects in which they are concerned, in order that a standard when promulgated is practicable and can be made economically.

The following list of organizations with which committees have cooperated will indicate the wide range of activities involved in such collaboration:

American Railway Association, Mechanical Division
American Railway Association, Purchases and Stores Division
American Petroleum Institute
American Society of Civil Engineers
American Society for Testing Materials
American Society of Mechanical Engineers
American Standards Association
American Transit Association
American Wood Preservers' Association
Central Committee on Lumber Standards
Chemical Warfare Service, U.S. Army
Forest Products Laboratory
Edison Electric Institute
Forged Tool Society
Joint Committee on Automatic Train Control
Joint Committee on Concrete and Reinforced Concrete
Joint Committee on Grade Crossing Protection
Joint Committee on Railway Sanitation
Manganese Track Society
National Bureau of Engineering Registration
National Scalemen's Association
Portland Cement Association
Rail Manufacturers' Technical Committee
Railway Fire Protection Association
University of Illinois, Engineering Experiment Station

Trackwork Plans.—For a number of years, the Committee on Track has actively cooperated with the Manganese Track Society, composed of the principal firms manufacturing frogs, switches, crossings, etc., in the preparation of plans for such track devices. To date, 187 plans, and specifications therefor, have been prepared and adopted. In view of developments, it has been found necessary to make a complete revision of these plans. The portfolio has been entirely reprinted, and copies will be available immediately after the convention. This is one of the outstanding achievements of the Association, and is in the direction of simplification and standardization. The preparation and printing of this Portfolio of Trackwork Plans involved an expenditure of upwards of twenty-five thousand dollars.

Research.—The Federal Coordinator of Transportation, in an address delivered at Chicago last November, referred to the research work carried on by large industries, and the benefits derived therefrom, and suggested that possibly similar results could be accomplished by railroads, with consequent benefit to the transportation industry. Possibly as a sequel to that suggestion, a Science Advisory Board, composed of leading scientists engaged in research

work for large industries, and educators, was appointed by President Roosevelt, to which were added six Railway Executives, for the purpose of ascertaining what railroads had done in the past or were doing currently, in the way of research or investigational work.

A survey has been made of the Association's activities along the line of this inquiry, and the results have been transmitted to the President of the American Railway Association, for presentation to the Science Advisory Board for its comments and recommendations.

Upon authorization of the Board of Directors of the American Railway Association, the Mechanical Division has set up a Research Bureau, with a Director in charge. The Freight Claim Division has also organized a staff, and is proceeding along somewhat similar lines.

At a meeting of the Board of Direction of your Association and of the General Committee of the Engineering Division, held on January 30, 1934, the question of establishing a similar Research Bureau for the Engineering Division was submitted for determination. As a result of the deliberations, it was voted to recommend to the American Railway Association the establishment of a Research organization, with a Director, Assistant Director, and the necessary clerical staff, which recommendation has been transmitted to the President of the ARA for action and authorization by its Board of Directors.

Honorary Membership.—During the year, Honorary Membership was conferred by the Board of Direction on George Watson Kittredge, second President of the Association, and on Dr. Arthur Newell Talbot, Chairman of the Special Committee on Stresses in Railroad Track, for outstanding contributions to the Science of Railway Engineering.

Changes in Titles of Committees.—The Board of Direction has approved changes in the titles of three Committees: Committee IX—Grade Crossings, has been changed to "Highways"; Committee XXV—Rivers and Harbors, to "Waterways and Harbors;" and Committee XIII—Water Service and Sanitation, to "Water Service, Fire Protection and Sanitation," these changes being considered as more in line with the functions of the respective committees.

Formation of a New Special Committee.—To dispense with a large amount of collaboration, the Board of Direction has authorized the formation of a new special committee, entitled "Special Committee on Roadway and Track Structure," its assignment reading, "Complete roadway and track for various loads and traffic densities."

Vacancy in Board of Direction.—By reason of leaving railway service, Lem Adams, who was elected a Director at the last annual meeting, resigned, and the Board appointed Dr. Hermann von Schrenk to fill the vacancy.

A Deserved Recognition.—J. C. Irwin, Representative of the American Railway Association—Engineering Division, on American Standards Association, has been elected Chairman of Standards Council of that important organization.

Translation of Table of Contents of Manual.—Emilio Lenhardtson, a valued member of the Association, with headquarters at Buenos Aires, Argentine, South America, has translated the table of contents of the 1929 Manual into the Spanish language for the information of Engineers in that country. This translation involved a large amount of painstaking labor.

Amendment to Constitution.—An amendment, proposed by the requisite number of members, relating to the manner of placing the names of candidates for offices on the ballot, when there is more than one candidate for any office, was submitted to the membership by letter-ballot. The result of the vote is:

For the amendment	636 votes
Against the amendment	91 votes
Defective votes (not counted)	39 votes

The amendment having been approved, it will become effective subsequent to the adjournment of the annual meeting.

Membership.—The membership rolls show a decrease from the number reported on a year ago. The appended table sets forth the present status of the membership:

Membership on rolls as of March 1, 1933		2311
Additions during the year		20
Reinstatements		24
		2355
Losses by death	21	
Resignations	65	
Dropped	241	327
Membership as of March 1, 1934		2028

The past four years have been exceedingly difficult for many of our members, and who have been adversely affected by the economic conditions. The Board of Direction has dealt with this situation in a sympathetic manner, which has been duly appreciated by those concerned. It is gratifying to report that improved conditions indicate the resumption of their membership affiliation of a substantial number of former members.

In the back of the current numbers of the Bulletin, a blank form of application is included. The individual members are requested to detach this form and hand it to an eligible prospect and urge that it be filled out and sent to the Secretary's office.

Deceased Members.—It is with deep regret that we record the loss of twenty-one valued and loyal members during the year. The names of our departed associates are given in a following page.

Finances.—The Financial Statement, shown in Exhibit 1, indicates that the Association's financial condition is very satisfactory, considering the business conditions prevailing for the past four years.

The losses in number of members has naturally affected our revenues, but with better or improved business, the lost ground will be recovered.

Acknowledgment.—The loyal, faithful and efficient services rendered by the staff is hereby gratefully acknowledged.

E. V. Gritch,

Secretary.

Personnel of Committees by Railways—1933

	Roadway	Ballast	Ties	Rail	Track	Buildings	Wooden Bridges and Trestles	Masonry	Grade Crossings	Signals and Interlocking	Records and Accounts	Rules and Organization	Water Service and Sanitation	Yards and Terminals	Iron and Steel Structures	Economics of Railway Location	Wood Preservation	Electricity	Uniform General Contract Forms	Economics of Railway Operation	Economics of Railway Labor	Shops and Locomotive Terminals	Rivers and Harbors	Standardization	Maintenance of Way Work Equipment	Stresses in Railroad Track	Clearances	Waterproofing of Railway Structures	Economics of Bridges and Trestles	TOTAL
Ann Arbor																					1									1
Atchison, Topeka & Santa Fe	3	2	2	2	2	1		2	1	1		1	2	1	1		2	1		1	1		1		1			1		29
Atlanta, Birmingham & Coast		1																												1
Atlantic Coast Line	1			1							1				1				2				1		1	1				9
Baltimore & Ohio	1	1		2	1	1	1	2	1	1	1	1	1	1	2		1	1	1	3	3	1		2	1	2	1		1	34
B. & O. Chicago Terminal			1						1														1							3
Belt Railway					1																									1
Bessemer & Lake Erie	1										1					1				1		1		1						6
Boston & Maine	2	1		1				1			2			2			1			1	1		1	1	2				1	17
Canadian National				2	3			1		1		1					1	1	1	2				1	1				1	16
Grand Trunk Western	1							1	1		1								1											5
Canadian Pacific		1		1	1	1		1		1		1	1	1	1	1						1			1		1			14
Central of Georgia			1	1		1											1		1				1							6
Central of New Jersey								1	1		1			1				2	1	1										8
Chesapeake & Ohio	3	2	2	3	4	2	2	2	3	1	6	2	3	1	1	2	1		1	4	2	2		3	3		2	1		58
Chicago & Eastern Illinois										1					1							1								3
Chicago & Northwestern	1			1	1					1	1	1	1		1			1		1					1			1		12
Chicago & Western Indiana									1													1	1							3
Chicago, Burlington & Quincy			2	1	3		1	1	2			1			1		1			1		1	1					1	1	18
Chicago Great Western							1									1														2
Chicago, Indianapolis & Louisville										1	1											1								3
Chicago, Mil. St. Paul & Pacific	1			1	1	1	1		1		1						1					2	2		2					14
Chicago, Rock Island & Pacific	1	2	1	2	2	1		2	2	1	1	1	2		1		2				1	1	1		1			1		26
Chicago Rapid Transit								1																						1
Cleveland Union Terminals																		1												1
Cincinnati Union Terminal														1																1
Colorado & Southern									1																					1
Columbia & Cowlitz							1																							1
Delaware, Lackawanna & Western		1	1	1	1			1	1				1						1	1			1	1	1	1	1			14
Delaware & Hudson														1						1										2
Detroit Rapid Transit									1																					1
Detroit & Toledo Shore Line											1																			1
Denver & Rio Grande Western							1					1												1					1	4
Duluth, Missabe & Northern							1				1												1							3
Elgin, Joliet & Eastern					1																	1			1					3

Personnel of Committees by Railways—1933

	Roadway	Ballast	Ties	Rail	Track	Buildings	Wooden Bridges and Trestles	Masonry	Grade Crossings	Signals and Interlocking	Records and Accounts	Rules and Organization	Water Service and Sanitation	Yards and Terminals	Iron and Steel Structures	Economics of Railway Location	Wood Preservation	Electricity	Uniform General Contract Forms	Economics of Railway Operation	Economics of Railway Labor	Shops and Locomotive Terminals	Rivers and Harbors	Standardization	Maintenance of Way Work Equipment	Stresses in Railroad Track	Clearances	Waterproofing of Railway Structures	Economics of Bridges and Trestles	TOTAL
Erie	2	2			1	1		1	1		1		1	2	1	1			2		2	1	2	1	1	1	1	1		26
Florida East Coast	2				1		1		1			1											1							7
Great Northern	1					1	1						1		1		1												1	7
Illinois Central	1			2	3	1	1		2	2	1	4	2	2			2	3	2	1	2	1	1	3	3			1		40
Illinois Terminal																					1									1
Indianapolis Union														1																1
Interborough Rapid Transit				1	1																									2
Johnstown & Stony Creek					1																									1
Kansas City Southern	1	1	1	1							1		1		1					2	1		1							11
Kansas City Terminal										1				1																2
Lake Superior & Ishpeming			1																				1							2
Lehigh Valley		1		1			1	1				1			1										1					7
Louisville & Nashville	1		1	1	1			1															1							6
Maine Central	1					1																			3			1		6
Minneapolis & St. Louis																									1					1
Mississippi Valley Lines											1																			1
Missouri-Kansas-Texas	1	1	1	1		1			1		1		2		1							1		1			1			13
Missouri Pacific Lines	1		1			1			1	2	1	1	1				1		1		2		1	1	1	1	1			18
Missouri Pacific Railroad	3		1		1		3	2	1		1	1	3	2		1			1	1		1	3	3	1	1		1	1	32
Mobile & Ohio							1																	1			1			3
Newburgh & South Shore			1																											1
New York, Chicago & St. Louis	1				1										1				1		2	1								7
New York, Ontario & Western											1																			1
New York Central Lines				1										1		1		1								1				5
Boston & Albany						1			1										1					1						4
Big Four	1		1					1	1		1				2	1			1		1	1			1					12
Michigan Central	1	1			2		1		1	1	1														1					9
New York Central Railroad	1	1	2	1	3	2			3	2	1	1	1	1	3		2	2		2	1	2	2	1	4	1	2	1		42
Nicholas, Fayette & Greenbriar					1																									1
Peoria & Eastern																				1										1
Pittsburgh & Lake Erie	1					1										1														3
New York, New Haven & Hartford	1	1		1		2			1	1	1			2	1			1		1			1	1	1		1	1	1	19
Norfolk & Western				1	1	1		1	1				1	1	1			1				1	1					1		12

Personnel of Committees by Railways—1933

	Roadway	Ballast	Ties	Rail	Track	Buildings	Wooden Bridges and Trestles	Masonry	Grade Crossings	Signals and Interlocking	Records and Accounts	Rules and Organization	Water Service and Sanitation	Yards and Terminals	Iron and Steel Structures	Economics of Railway Location	Wood Preservation	Electricity	Uniform General Contract Forms	Economics of Railway Operation	Economics of Railway Labor	Shops and Locomotive Terminals	Rivers and Harbors	Standardization	Maintenance of Way Work Equipment	Stresses in Railroad Track	Clearances	Waterproofing of Railway Structures	Economics of Bridges and Trestles	TOTAL
Norfolk Southern	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	1	----	----	----	----	----	2
Northern Pacific	----	----	1	1	1	1	----	1	2	----	1	1	1	----	----	2	2	----	----	1	1	----	----	1	----	----	----	----	----	17
Pennsylvania	1	3	3	3	2	----	----	2	1	2	2	1	3	2	1	2	2	1	2	1	2	----	1	2	2	1	2	----	----	44
Pere Marquette	1	----	1	----	1	----	----	----	1	----	1	----	----	----	1	----	----	----	----	----	1	----	----	----	1	----	----	----	----	8
Pittsburgh, Chartiers & Youghiougheny	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1
Pittsburgh & West Virginia	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1
Reading	----	1	----	1	1	1	----	1	1	----	1	----	2	----	1	1	----	1	----	----	----	----	----	1	1	----	----	----	----	14
Richmond, Fredericksburg & Potomac	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	2
Rutland	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1
St. Louis-San Francisco	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	1
St. Louis Southwestern	----	----	----	----	----	----	----	----	----	----	1	----	1	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	3
Seaboard Air Line	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	1	----	----	----	1	----	----	----	----	----	----	3
Southern	1	----	----	1	2	----	----	----	----	1	----	1	1	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	8
Soo Line	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	1	----	----	----	----	2
Southern Pacific (Northwestern Pacific)	2	1	1	2	1	----	1	----	2	1	----	----	----	1	----	1	2	1	----	1	1	----	1	----	1	----	----	----	----	20
Temiskaming & No. Ontario	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1
Term. R. R. Assn. of St. Louis	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1
Texas & Pacific	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	2
Texas Pacific—Missouri Pacific Terminal	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	1	----	----	----	----	----	----	----	2
Third Avenue Railway	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1
Toronto Terminals	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	2
Union Pacific	----	----	1	2	----	----	1	----	----	1	----	1	1	----	1	----	----	----	----	----	1	----	----	1	----	----	----	----	----	10
Union Railway (Pittsburgh)	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1
United Railway & Electric Co.	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1
Utah	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	1
Wabash	----	----	1	----	----	1	----	----	1	----	1	1	2	2	----	1	----	----	----	----	1	----	----	----	1	----	----	----	----	12
Wheeling & Lake Erie	----	1	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	2
Western Maryland	----	----	----	----	----	----	----	----	1	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	2
Non-Railroad	1	6	1	2	10	4	4	11	4	----	3	1	1	13	14	4	12	----	3	7	2	3	2	----	1	12	----	3	1	125
Foreign	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	1	----	----	----	----	----	----	----	----	----	2
Total	41	31	31	42	58	28	25	40	46	24	42	25	37	43	42	21	36	18	26	38	31	27	33	30	43	22	14	15	9	918

GEOGRAPHICAL DISTRIBUTION OF MEMBERSHIP

United States and Possessions

Alabama	4
Arizona	4
Arkansas	19
California	53
Colorado	12
Connecticut	22
Delaware	1
District of Columbia	28
Florida	15
Georgia	22
Hawaii	1
Idaho	3
Illinois	287
Indiana	33
Iowa	16
Kansas	36
Kentucky	27
Louisiana	12
Maine	11
Maryland	43
Massachusetts	45
Michigan	45
Minnesota	65
Mississippi	7
Missouri	133
Montana	8
Nebraska	21
New Hampshire	5
New Jersey	40
New Mexico	1
New York	170
North Carolina	19
North Dakota	1
Ohio	148
Oklahoma	9
Oregon	3
Pennsylvania	168
Philippine Islands	2
Puerto Rico	1
Rhode Island	3
Tennessee	16
Texas	82
Utah	8
Vermont	7
Virginia	86
Washington	19
West Virginia	26
Wisconsin	10
Wyoming	1
	1798

Other Countries

Canada	113
Japan	28
Mexico	14
Union Soc. Sov. Republic	8
China	9
Argentine	6
Australia	7
Brazil	6
England	4
Manchukuo	5
Central America	5
Cuba	4
India	6
Africa	2
Czecho-Slovakia	2
Columbia	2
Germany	2
Siam	1
Bolivia	1
France	1
Scotland	1
Spanish Honduras	1
Sudan	1
Switzerland	1
	230

RAILWAYS REPRESENTED IN THE A.R.E.A., MILEAGE AND NUMBER OF MEMBERS

	Mileage	*Number of Members*
Akron, Canton & Youngstown Railway	171	1
Algoma Central & Hudson Bay Railway	322	1
Alton & Southern Railroad	31	1
Arkansas Railroad Company	20	1
Atchison, Topeka & Santa Fe Railway System	13,335	64
Includes Gulf, Colorado & Santa Fe		
Panhandle & Santa Fe		
Atlanta, Birmingham & Coast Railroad	639	3
Atlanta & West Point Railroad	227	1
Atlantic Coast Line Railroad	5,300	17
Baltimore & Ohio Railroad System	6,398	69
Alton Railroad	979	5
Bangor & Aroostook Railroad	604	2
Bessemer & Lake Erie Railroad	226	7
Bingham & Garfield Railway	40	1
Boston & Maine Railroad	2,081	23
Brantford Steam Railroad	....	1
Brooklyn Manhattan Transit Corporation	9	1
Butte, Anaconda & Pacific Railway	65	1
Canadian National Railways	22,039	54
Central Vermont Railway	457	2
Grand Trunk Western Railway	1,441	7
Canadian Pacific Railway	16,384	32
Central of Georgia Railway	1,976	9
Central Railroad of New Jersey	689	11
Chesapeake & Ohio Railway	3,145	79
Chicago & Eastern Illinois Railway	939	5
Chicago, Burlington & Quincy Railroad	9,248	19
Chicago Great Western Railroad	1,509	7
Chicago, Indianapolis & Louisville Railway	647	3
Chicago, Milwaukee, St. Paul & Pacific Railroad	11,243	26
Chicago Railway Terminal Commission	....	1
Chicago Rapid Transit Company	....	1
Chicago, Rock Island & Pacific Railway	7,611	33
Chicago, St. Paul, Minneapolis & Omaha Railway	1,692	2
Chicago Union Station Company	....	1
Chicago, West Pullman & Southern Railroad	13	1
Chicago & Illinois Midland Railway	132	1
Chicago & Northwestern Railway	8,443	11
Chicago & Western Indiana Railroad	68	7
Cincinnati, New Orleans & Texas Pacific Railway	336	1
Cincinnati Union Terminal Company	....	1
Cleveland Union Terminals Company	60	2
Colorado & Southern Railroad	1,030	1
Colorado & Wyoming Railroad	105	1
Columbia & Cowlitz Railway	8	1
Danville & Western Railroad	82	1
Delaware & Hudson Company	876	11
Delaware, Lackawanna & Western Railroad	998	19
Denver & Rio Grande Western Railroad	2,514	3
Des Moines Union Railway	5	1
Detroit & Toledo Shore Line Railroad	50	4
Detroit, Toledo & Ironton Railroad	474	2
Dominion Atlantic Railway	304	1
Duluth, Missabe & Northern Railway	564	5
Elgin, Joliet & Eastern Railway	447	5
Erie Railroad	2,558	35
Florida East Coast Railway	839	6
Fort Smith & Western Railway	250	1
Fort Worth & Denver City Railway	804	2
Georgia & Florida Railroad	464	1
Georgia Railroad	329	1
Great Northern Railroad	8,695	17
Gulf, Mobile & Northern Railroad	954	1
Hudson & Manhattan Railroad	9	1
Huntingdon & Broad Top Mountain Railroad & Coal Company	74	1
Illinois Central System	6,720	47
Illinois Terminal Railroad System	543	3
Indianapolis Union Railway	16	1
Interborough Rapid Transit Company	....	2
Interstate Railway	74	1
Johnstown & Stony Creek Railroad	14	1
Kansas City Southern Railway	857	14
Kansas City Terminal Railway	26	3

	Mileage	Number of Members
Kentucky & Indiana Terminal Railroad	8	1
Key System Transit Company	70	1
Lake Superior & Ishpeming Railroad	160	1
Lehigh & Hudson River Railway	97	1
Lehigh & New England Railroad	227	2
Lehigh Valley Railroad	1,363	9
Louisiana, Arkansas & Texas Railway	256	1
Louisiana & Arkansas Railway	608	2
Louisville & Nashville Railroad	5,166	12
Maine Central Railroad	1,045	7
Mexican Railway	322	1
Midland Continental Railroad	69	1
Midland Valley Railroad	363	1
Minneapolis & St. Louis Railroad	1,628	2
Minneapolis, St. Paul & Sault Ste. Marie Railway	4,337	8
Minnesota Transfer Railway	140	1
Mississippi Central Railroad	150	1
Missouri & North Arkansas Railway	365	1
Missouri–Kansas–Texas Lines	3,188	23
Missouri Pacific Lines:		
Missouri Pacific	2,333	19
Union Railway	18	1
Missouri–Illinois Railroad	202	2
Missouri Pacific Railroad	7,472	72
Mobile & Ohio Railroad	1,202	2
Montana, Wyoming & Southern Railroad	27	1
Montour Railroad	58	1
Montreal Tramways Company	....	1
Muncie & Western Railroad	1	1
Nashville, Chattanooga & St. Louis Railway	1,203	4
National Railways of Mexico	8,324	9
Newburgh & South Shore Railway	82	1
New Orleans & Lower Coast Railroad	60	1
New York Central Lines:		
Boston & Albany Railroad	402	10
Cleveland, Cincinnati, Chicago & St. Louis Railway	2,333	21
Indiana Harbor Belt Railroad	120	2
Michigan Central Railroad	1,858	12
Peoria & Eastern Railway	212	3
Pittsburgh & Lake Erie Railroad	235	3
New York Central Railroad	5,478	69
Nicholas, Fayette & Greenbrier Railroad	....	1
New York, Chicago & St. Louis Railroad	1,691	15
New York, New Haven & Hartford Railroad	2,069	25
New York, Ontario & Western Railway	569	4
Niagara Junction Railway	4	1
Norfolk & Western Railway	2,233	18
Norfolk Southern Railway	933	3
Northern Pacific Railway	6,914	37
Northwestern Pacific Railroad	408	2
Oklahoma Railway	119	1
Pennsylvania Railroad	10,536	69
Long Island Railroad	400	1
Peoria & Pekin Union Railway	159	2
Pere Marquette Railway	2,321	12
Piedmont & Northern Railway	128	1
Pittsburgh & West Virginia Railway	138	1
Pittsburgh, Chartiers & Youghiogheny Railway	18	1
Pittsburgh, Lisbon & Western Railroad	23	1
Pullman Railroad	6	1
Quanah, Acme & Pacific Railway	128	1
Reading Company	1,490	25
Pennsylvania-Reading Seashore Lines	509	2
Richmond, Fredericksburg & Potomac Railroad	118	2
Rio Grande & Eagle Pass Railway	25	1
Rutland Railroad	413	2
Sacramento Northern Railroad	274	1
Sand Springs Railway	32	1
San Francisco, Napa & Calistoga Railway	46	1
Savannah & Atlanta Railway	147	1
Seaboard Air Line Railway	4,386	16
Southern Railway System	6,869	28
Southern New England Railroad	....	1
Southern Pacific System	9,102	29
Southern Pacific Company of Mexico	1,370	4
Southern Pacific Lines in Texas & Louisiana	4,488	8
Houston & Texas Central Railroad	....	1
St. Louis–San Francisco Railway	5,762	6
St. Louis Southwestern Railway	1,885	8
Tela Railroad	244	2

	Mileage	Number of Members
Temiskaming & Northern Ontario Railway	532	1
Tennessee, Alabama & Georgia Railway	95	1
Tennessee Central Railway	288	1
Tennessee Coal, Iron & Railroad Company	....	1
Terminal Railroad Association of St. Louis	95	4
Texarkana & Fort Smith Railway	81	1
Texas & Pacific Railway	2,091	11
Texas Pacific–Missouri Pacific Terminal Railroad of New Orleans	10	2
Toledo & Western Railroad	79	1
Toledo, Peoria & Western Railroad	239	1
Toledo Terminal Railroad	29	3
Toronto, Hamilton & Buffalo Railway	111	1
Toronto Harbor Commission	....	1
Toronto Terminals Railway	....	3
Union Pacific System:		
Los Angeles & Salt Lake Railroad	1,249	3
Oregon Short Line Railroad	2,504	5
Oregon–Washington Railroad & Navigation Company	2,316	1
Union Pacific Railroad	3,768	17
Union Railroad (Pittsburgh)	45	2
Utah Railway	111	1
Virginian Railway	608	7
Wabash Railway	2,480	28
Ann Arbor Railroad	332	4
Washington, Idaho & Montana Railway	50	1
Washington Terminal Company	2	1
Waterloo, Cedar Falls & Northern Railway	112	2
Western Maryland Railroad	892	10
Western Pacific Railroad	1,163	4
Wheeling & Lake Erie Railway	537	5
Yosemite Valley Railroad	78	1

Deceased Members

MORTON L. BYERS
Former Consulting Engineer, Delaware & Hudson Company; Charter Member

J. C. AUSTIN
Assistant Vice-President, Southern Railway System

WILLIAM A. CHRISTIAN
Assistant Engineer, U. S. Engineer's Office, Chicago

CHARLES S. CHURCHILL
Retired Chief Engineer, Norfolk & Western Railway; Charter Member; Honorary Member; Past-President

F. L. DODGSON
Consulting Engineer, General Railway Signal Company

F. H. ELLSWORTH
Division Engineer, New York, New Haven & Hartford Railroad

A. I. GAUTHIER
Assistant Division Engineer, Boston & Maine Railroad

JAMES H. GIBBONEY
Chemist, Norfolk & Western Railway; Chairman, Committee on Arrangements, AREA

B. E. HOLLOWAY
Retired Executive President, National Railways of Mexico

C. H. MITCHELL
Chief Lumber Inspector, Louisville & Nashville Railroad

JEROME NEWMAN
Consulting Engineer, San Francisco, Calif.

Deceased Members

ALEX MACGLASHAN
Civil Engineer, Jersey City

R. V. REAMER
Superintendent, Central Railroad of New Jersey

E. H. SHIPMAN
Corporate Engineer, The Lehigh Coal and Navigation Company

J. P. SNOW
Retired Chief Engineer, Boston & Maine Railroad; Consulting Engineer; Vice-President, AREA, 1908; Director, 1905–1907; Chairman, Committee on Iron and Steel Structures, 1902–1907

HENRY M. SPERRY
Publicity Representative, Union Switch & Signal Company and General Railway Signal Company

W. T. TAYLOR
District Engineer, Cleveland, Cincinnati, Chicago & St. Louis Railway

GEORGE E. TEBBETTS
Structural Engineer, Chicago Rapid Transit Company

SIR HENRY W. THORNTON, K.B.E.
Retired Chairman and President, Canadian National Railways

H. N. WHITE
Assistant Engineer, Norfolk & Western Railway

L. C. WINSHIP
Electrical Engineer, Boston & Maine Railroad

Exhibit 1

FINANCIAL STATEMENT FOR CALENDAR YEAR ENDING DECEMBER 31, 1933

Balance on hand January 1, 1933 ..... $71,427.62

RECEIPTS

Membership Account		
Entrance Fees	$ 190.00	
Dues	18,090.46	
Binding Proceedings	1,633.16	
Badges	3.50	
Sales of Publications		
Proceedings	1,574.05	
Bulletins	1,282.37	
Manual	340.05	
Specifications	332.85	
Track Plans	144.20	
Advertising		
Publications	623.80	
Interest Account		
Investments	2,120.02	
Bank Balance	33.32	
Miscellaneous	42.45	
Total	$26,410.23	

DISBURSEMENTS

Salaries	$ 8,714.00	
Proceedings	4,352.28	
Bulletins	4,579.48	
Manual	35.00	
Track Plans	.....	
Stationery and Printing	440.58	
Equipment	100.00	
Rents, Light, etc.	830.50	
Supplies	88.38	
Expressage	247.99	
Postage	524.45	
Exchange	78.16	
Committee Expenses	103.33	
Officers' Expenses	28.03	
Annual Meeting	805.47	
Refund Dues, etc.	47.00	
Audit	200.00	
Pension (A. K. Shurtleff)	1,200.00	
Miscellaneous	70.59	
Total	$22,445.24	
Excess of Receipts over Disbursements		$ 3,964.99
Balance on hand December 31, 1933		$75,392.61

Consisting of

Bonds	$70,691.02
Cash in Northern Trust Co. Bank	3,755.30
Cash in City National B. & T. Co.	325.55
Cash in Royal Bank of Canada	595.74
Petty Cash	25.00
	$75,392.61

REPORT OF THE TREASURER

Balance on hand January 1, 1933		$71,427.62
Receipts during 1933	$26,410.23	
Paid out on Audited Vouchers, 1933	22,445.24	
Excess of Receipts over Disbursements	3,964.99	
Balance on hand December 31, 1933	$75,392.61	

Consisting of bonds at cost	$70,691.02
Cash in Northern Trust Co. Bank	3,755.30
Cash in City National Bank	325.55
Cash in Royal Bank of Canada	595.74
Petty Cash Fund	25.00
	$75,329.61

STRESSES IN TRACK FUND

Balance on hand January 1, 1933	$ 3,211.75
Received from Interest during 1933	213.88
Total	$ 3,425.63
Paid out on Audited Vouchers during 1933	3,398.92
Balance of Fund on hand December 31, 1933	$ 26.71

A. F. Blaess, *Treasurer.*

I have made an audit of the accounts of the American Railway Engineering Association for the year ending December 31, 1933, and find them to be in accordance with the foregoing Financial Statements.

Charles Campbell, *Auditor.*

GENERAL BALANCE SHEET

December 31, 1933

Assets	1933	1932
Dues from Members	$ 4,423.50	$ 5,487.96
Due from Sales of Publications	188.65	201.25
Due from Advertising	50.00	120.00
Due from Rail Investigations	686.38	691.50
Furniture and Fixtures	450.00	506.00
Gold Badges	37.50	40.00
Publications on hand (Estimated)	2,000.00	2,000.00
Manual (1929)		1,700.00
Extensometers	350.00	400.00
Investments (Cost)	70,691.02	67,316.02
Interest on Investments (Accrued)	1,364.97	542.79
Cash in Northern Trust Co. Bank	3,755.30	
Cash in City National Bank & Trust Company	325.55	2,859.15
Cash in Royal Bank of Canada	595.74	1,227.45
Petty Cash	25.00	25.00
Total	$84,943.61	$83,117.12

Liabilities		
Member's Dues Paid in Advance	$ 3,967.50	$ 4,356.50
Surplus	80,976.11	78,760.62
Total	$84,943.61	$83,117.12

Exhibit 2

SYNOPSIS OF COMMITTEE REPORTS

Roadway (Geo. S. Fanning, *Chairman*).—The current report is the conclusion of the subject of "Methods of Roadbed Drainage," in accordance with the plan adopted in 1931. The present report covers (c) Maintenance of ditches and drains; special problems of maintenance—soft spots and water pockets; and slides. Changes in the Manual are recommended in order to bring the definitions and the Specifications for the Formation of the Roadway in harmony with the recommended practice adopted for roadway drainage, to withdraw from the Manual present matter on slides, water pockets, soft spots and ditching, the substance of which is included in the current report or is obsolete, and to replace the illustrations in the Manual relating to drainage with more comprehensive plates. . . . The practice of various railroads as to jacking culvert pipe through fills is reported on and illustrated. The conclusions of the Committee are that where conditions are suitable, the placing of pipe culverts by the jacking process is feasible and will save from 30 to 50 per cent of the cost of placing the pipe by the open trench method and will be cheaper than tunneling. The advantages of the method, cited by the Committee are—usually lower cost; no interruption to traffic, minimum disturbance of roadbed, and consequently little or no subsequent settlement. . . . The subject, bearing power of soils, has been enlarged upon this last year by the assignment of the broader field of the bearing power and other physical properties of soils in addition to consideration of their effect on roadbed performance. A terminology of soils is presented as a preliminary listing of soil characteristics. The current report deals with terms identifying soils, texture, structure, consistence, compactness and cementation. . . . A year ago, methods of protecting against drifting snow and of snow removal on the line and in yards and terminals was reported on. In the current report the assignment was modified and treated under the title, methods of protecting against drifting snow and opening snow blockades. The report has been subdivided into protection against drifting snow and opening snow blockades, and providing for revision of certain material in the Manual. . . . A new subject, methods of protection against drifting sand, has been extensively reported on in the current report. The Committee has accumulated a large amount of interesting information in regard to methods for protecting against this menace from various parts of the world.

Ballast (A. P. Crosley, *Chairman*).—Samples of gravel ballast have been collected through cooperation of railroads and gravel producers, and subjected to abrasion, crushing, specific gravity, absorption, grading, weight, void, and soundness tests. Information concerning the service record in the track of most of these samples has been furnished the Committee by railroads. It is proposed to continue these tests and report thereon in future. . . . Further study has been given to the specifications for stone ballast, including best method of testing resistance to weathering; study has also been given to the subject of cementing value. The Committee contemplates initiating a cooperative series of cementing value tests, with the hope of obtaining information of practical value for use in specifications for ballast. . . . The Committee has endeavored to secure data on comparative cost of maintaining track on various kinds of ballast, but little information has been obtained. . . . As a result of its study on the subject, proper depth and kind of subballast, the Committee recommends a revision of the conclusions in the Manual under the heading, proper depth of ballast. In considering the subject, a distinction has been made between new construction and old established lines.

Ties (W. J. Burton, *Chairman*).—The Committee proposes a revision of the Specifications for Cross- and Switch-Ties, relating to split and dimensions, and presents arguments in support thereof. . . . The benefits to railroads of strictly adhering to the standard tie specifications are pointed out. . . . The customary annual report on installations of substitute ties is presented, together with a summary of tests of substitute ties now in progress.

. . . The tie renewal statistics for railroads of the United States were issued in the June Bulletin (see page 71, No. 356). The corresponding data for the three principal Canadian railways is included in the current report. . . . A comprehensive report is presented on standard spacing of spike holes for ties preadzed and bored for standard rail sections of 90-lb. to 131-lb. inclusive. A number of recommendations are made and request that the subject be reassigned for further study. . . . A particularly interesting and valuable report is that relating to a method of predicting tie renewals, including a change from untreated to treated ties. The report covers definitions of terms; general discussion of renewal predictions; procedure for making predictions; method of determining approximate average life of ties in track. . . . The type of tie plate best adapted for use with pre-adzed ties is discussed. The Committee recommends a plate of adequate size and proper design to afford maximum protection from mechanical wear. If plates with ribs are used, the Committee recommends the grooving for these ribs in connection with pre-adzing. . . . A study has been made of the economy of use of tie plates which are secured to the tie independently of the rail fastenings, with particular reference to the effect on tie life. The replies to a questionnaire on the subject are commented on. . . . The Committee presents a comprehensive report on methods of inspection for renewal of ties, checking thereof and adherence thereto. The replies to a questionnaire are analyzed and commented on. As a result of its study, the Committee offers a series of conclusions, which in its judgment, under most conditions, will bring about safe and economical control of tie renewals.

Rail (Earl Stimson, *Chairman*).—The Committee proposes a number of changes in the chapter on "Rail" in the Manual. . . . Progress is reported on the joint investigation being conducted at the University of Illinois on the cause and remedy for transverse fissures and other rail failures. This investigation is now in its third year and definite progress is being made. . . . One of the features of the annual report is the compilation of rail failure statistics. The current report contains the statistics for the year 1932. Similar statistics are presented on transverse fissure failures. . . . The operations of the ARA Detector Car are reported on, indicating that a total of 6600 track miles were tested during the year. . . . The Committee has given further study to the cause and prevention of rail battering. Various methods of heat treating rail ends are described, and the Committee recommends that the heat treating of rail ends be generally followed in the case of new rail, cropped rail, or where rail batter has not progressed to an objectionable extent. . . . As a result of its study of the question of rail lengths in excess of 39 ft. (the present standard), the Committee reports that it feels the majority of roads are not prepared at this time to agree on a standard length in excess of 39 ft. . . . The results of tests of alloy and heat treated carbon steel rails are presented. . . . During the year, the Committee gave intensive study to redesigning rail sections heavier than 100-lb. per yard, so as to obtain the most economical distribution of metal with the maximum strength of section. A section weighing 112.4-lb. per yard was developed. Action on the Committee's recommendation could not be deferred until the annual meeting, the section was therefore submitted to the membership by letter-ballot, dated July 1, 1933. The recommendation was approved by a large majority vote. The new section supersedes the former 110-lb. RE section. . . . The subject of design of joint bars for RE rail sections was assigned to the Committee during the year, with instructions for early report. This topic was also given immediate and preferred attention, and a joint bar section and assembly for use with the 112-lb. RE section was developed. As there was need for early action, the Committee's recommendation was submitted to letter-ballot. dated January 20, 1934. A joint-bar section and assembly for use with the 131-lb. RE section has been issued as a Supplemental Report.

Track (C. J. Geyer, *Chairman*).—Intensive study has been given to revision of the chapter on "Track" in the Manual, and a number of important changes are recommended. An addition to the specifications for soft steel cut track spikes is submitted. As information and for criticism, plans are presented for 9/16-inch and ⅝-inch raised throat cut track spikes. . . . Dur-

ing the year, study has been given to plans and specifications for track tools, resulting in a series of plans and specifications, which are offered for approval. The Committee proposes making further study for additional tools adapted to use in modern track maintenance and construction, particularly as regards tools used in laying and handling heavy rail. . . . Specifications for adjustable guard rail clamps are offered for approval. . . . With the view of securing information relative to possible limits in the use of roller bearings on curves, a circular of inquiry was sent to large manufacturers of roller bearings, and the data obtained is submitted as information. . . . On September 21, 1933, the subject of design of tie plates for RE rail sections was assigned to the Track Committee. As result of a thorough study given these instructions, the Committee has prepared a series of plans for tie plates, which are offered for approval as recommended practice. On account of the urgent need for tie plate standards and due particularly to the adoption of the new rail sections, the plans are submitted for approval as recommended practice at this time rather than as information. . . . Progress is reported on the practicability of using reflex units for switch lamps and targets. . . . The replies received in answer to a questionnaire on desirable tightness of track joints and effect upon life of rail and joints, and of loose joints, have been summarized and from these replies a series of conclusions have been derived. . . . An interesting report is that on methods of reconditioning of rail ends, fastenings, frogs and switches in track. A comprehensive tabulation of replies to a questionnaire is included. . . . A final report is made on damage to track and devices due to brine drippings from refrigerator cars, including the conclusions and recommendations of a joint sub-committee.

Buildings (G. A. Rodman, *Chairman*).—Revised Specifications for Built-up Roofing are submitted to supersede similar specifications in the Manual. . . . Continuing its assignment, preparation of Specifications for Railway Buildings, sections on steel chimneys—welded; genuine wrought iron chimneys; built-up roofing; wood screens, and metal screens, are presented for information and criticisms. The preparation of these various sections, now numbering over thirty, has extended over a series of years, and is of great practical value to the Railway Engineer. . . . An interesting report is that on the subject of the relative merits of wood and fireproof roof structures, including wood, hollow tile fireproofing, concrete, cement tile, etc. The report includes a table on the relative merits of different types of wood structures. . . . The Committee has given active study to the causes of dust explosions in grain elevators and to methods of obviating the hazard. The Department of Agriculture reports that during the last fourteen years dust explosions in the United States in plants handling grain and grain products caused the loss of 277 lives, injury to 487 employees, and property damage amounting to more than thirty million dollars. The Committee has assembled a large amount of data and presents it in interesting form. A series of conclusions are offered, outlining methods by means of which dust explosions can be reduced.

Wooden Bridges and Trestles (H. Austill, *Chairman*).—A number of minor revisions of the chapter on Wooden Bridges and Trestles as now appearing in the Manual are submitted. . . . Under the assignment, overhead wooden or combination wooden and steel highway bridges, study has been given to the specifications for timber piles included in the Manual, and it is considered that the dimensions of piles as specified are larger than required for use in highway bridges. A table of dimensions for first-class piles for highway bridges is presented. . . . On the subject, design of standard wooden trestles for heavy loading, the Committee states that the present plans in the Manual provide for a live load of Cooper's E–45 and E–60, and that its study of modern locomotives indicates loading considerably in excess of these design loads. A table is presented giving the axle loading and Cooper's rating for 14-ft. span for a few typical modern locomotives; another table gives a comparison of unit stresses for a selected number and size of stringers for open and ballasted deck. A statement is presented prepared by J. A. Newlin, a member of the Committee, giving the results of an extensive series of tests to determine horizontal shear stresses and their distribution in the beam. . . .

A valuable report is submitted by the Committee on methods of strengthening existing bridges. . . . During the year the Committee has given study to the design of washers, separators, cap stringer straps, and other trestle fastenings, and considered the practice of a number of roads. The Committee contemplates preparing designs of washers, separators, and fastenings and present them in a future report.

Masonry (M. Hirschthal, *Chairman*).—Progress is reported on the subject of reinforced concrete arches, and the Committee indicates it proposes to review the material now presented and that included in previous reports, and to submit to the next annual meeting for approval as recommended practice specifications for the design and construction of reinforced concrete arches for railroad loadings. . . . Drawings of reinforced concrete trestles design for E–60 loading are submitted for approval as recommended practice. . . . The Committee continues to report on progress in the science and art of concrete manufacture, presents a valuable contribution on vibration in placement of concrete, including a selected bibliography on high-frequency vibration of concrete. Other phases of this same general subject are treated under the sub-headings, central mixed and transit mixed concrete, and segregation. . . . On the subject of foundations, definitions for "Foundations" and for "Substructure" are offered for approval. A general specification for foundations for railway structures is submitted for information and criticism. . . . Tentative specifications for lining railway tunnels with concrete are offered for information and comments. . . . An interesting report is that on pneumatically projected concrete, including tentative specifications for "shotcrete". . . . The Committee has continued its study of design of expansion joints involving masonry structures, and has collected a number of plans covering various types of joints involving masonry structures under varying conditions. These sketches are illustrated, together with comments thereon.

Grade Crossings (J. G. Brennan, *Chairman*).—Active study over a period of two years has been given to the preparation of specifications for street crossings over railway tracks, both steam and electric. Four specifications are submitted, the first three for approval, the fourth as information, namely: Specifications for preparation of track structure, width of crossing and approaches for construction of street crossings over railway tracks; specifications for the construction of rail type street crossings; specifications for the construction of wood plank street crossings; and specifications for the construction of highway crossings surfaced with oil processed gravel. . . . An interesting report is submitted on the relative economy of different types of grade crossings. The report is grouped under plank, bituminous, concrete, metal and paved crossings. A statement is included giving some of the advantages and disadvantages of the various types of crossings. . . . A valuable report is that on the proper vertical curves on highways for grade separation projects, together with a recommendation that depression or elevation of highways required for separation from railroad grades be effected with the minimum of vertical curvature required for safety and utility. . . . The Committee has investigated the merits and economy of the "stop-and-go" type of signal with red and green illuminated aspects, as a protective device at highway-railroad grade crossings, under usual conditions and under special conditions, and concludes that such signals should not be used for the protection of railroad-highway grade crossings where they are operated exclusively by the passage of trains, but that their use should be confined to special locations where their observance can be enforced by police power.

Signals and Interlocking (P. M. Gault, *Chairman*).—The province of this Committee is to keep the members of the AREA informed of developments in signaling and interlocking. In the current report, the developments in automatic train control are recorded. In previous years the Committee has presented reports showing the savings and increased efficiency secured in railway operation by signal indications in lieu of train orders and timetable superiorities. The present report relates to intangible benefits and savings difficult to determine accurately provided by centralized traffic control installation.

. . . The report gives a synopsis of the principal current activities of the Signal Section, supplemented with list and references by number of adopted specifications, designs, and principles of signaling practice.

Records and Accounts (C. C. Haire, *Chairman*).—One of the noteworthy accomplishments of this group during the year is the revision of the conventional signs for use on railway profiles, right-of-way and track maps. The preparation of this document has involved a very large amount of painstaking labor on the part of this Committee. . . . Another valuable contribution is the report on joint facility records. Suitable forms for handling joint facility records are submitted, with the view of making the billing between roads less troublesome, and of simplifying the rendering and checking of joint facility bills. . . . Revised forms for bridge inspection report, wood boxes and pipe culvert inspection report, and bridge, trestle and culvert inspection report forms are submitted to supersede corresponding forms now in the Manual. . . . Under its assignment, statistical requirements of operating, accounting and other departments with respect to maintenance of way and structures, forms are submitted to cover the recapitulation and distribution of material. . . . In collaboration with the Committee on Water Service, an up to date system of Water Service Department forms has been developed in lieu of the present obsolete forms in the Manual. . . . The enactment of the Emergency Transportation Act of 1933 has affected the valuation procedure through amendment of the Valuation Act of the Interstate Commerce Commission. On account of this revision of the Valuation Act, there is a tendency to minimize the future importance of the property records of the carriers which have been inaugurated under the activities of the Valuation Order No. 3. The Depreciation Order, the tentative revised classification, and Valuation Order No. 3 are so closely tied into each other that activities with respect to one should be closely coordinated with the activities of the others if economical handling is to be obtained. . . . Attention is called to the repeal of the recapture clause of the Interstate Commerce Act, and that payments made thereunder have been ordered returned to the carriers involved. . . . The Committee reports progress on its assignment, methods for avoiding duplication of effort and for simplifying and coordinating work under the requirements of the Interstate Commerce Commission.

Rules and Organization (E. H. Barnhart, *Chairman*).—For a number of years this Committee has been engaged in the preparation of a Manual of Rules for the Guidance of Employees of the Maintenance of Way Department. Continuing this study, the Committee presents in its current report rules for the maintenance of bridges—masonry and composite structures; rules for the maintenance of telegraph and telephone lines and appurtenances; revised rules on fire protection, all of which are offered for approval. . . . Last year the Committee submitted a report on appropriate titles for Assistant Engineers in all departments. No comments or criticism having been received during the year, the report is now offered for approval as recommended practice.

Water Service and Sanitation (R. C. Bardwell, *Chairman.*)—For several years, this Committee has made progress reports on the cause and extent of pitting and corrosion of locomotive boiler tubes and sheets, and has made available a large amount of interesting data on the subject in Vol. 23, 25, 26, and 33 of the Proceedings. The current report contains additional material on this live subject. . . . During the year the Committee has endeavored to summarize the monetary value of the various methods of water treatment, and presents the results of its study in an interesting report. . . . An exceedingly valuable and comprehensive report is that on developments in pipe joints. Historical data on the methods of the transportation of water is presented. Over one hundred types of joints are described and illustrated. . . . This Committee is also concerned with sanitation, and in connection with this phase of its scope, it is giving study to the essentials of mosquito control. A monograph on this topic by the Committee forms a valuable contribution to the report. . . . The Committee has carried on an extended investigation

of disinfectants, fumigants and cleaning materials. The Committee presents an outline of correlated purposes for which disinfectants, fumigants, deodorants, and cleaning materials are used on railways, on which it proposes to render a detailed report in the future.

Yards and Terminals (M. J. J. Harrison, *Chairman*).—Under Revision of Manual, the Committee proposes changes of specified items of the section of the Manual covering Freight Yards; also, changes in the Rules for the Location, Maintenance, Operation and Testing of Railway Track Scales. A definition of a standard test of a railway track scale is offered for approval. . . . On the subject, grain elevator storage yards and plant tracks, the Committee presents an analysis of replies received to a questionnaire, which forms the basis of its report. The general types of grain elevators are described, and a statement showing characteristics of 47 grain elevators served by railroads is included in the report. Layouts of grain elevator storage yards and plant tracks are given. . . . In its report on Hump Yards, submitted a year ago, the Committee presented information on what is termed the graphic method to be used in designing gradients in connection with the application of car retarders to hump yard operation. Two graphic methods were described, "A" and "B". The current report contains a further discussion concerning application under graphic method "B". . . . Proposed Specifications for the Manufacture and Installation of Motor Truck, Built-in, Self-Contained and Portable Scales for Railway Service are submitted as information and criticism. They are intended to supersede corresponding specifications in the Manual which are recommended be withdrawn. . . . The customary bibliography on subjects pertaining to Yards and Terminals appearing in current periodicals is an interesting and valuable feature of the report. . . . Study has been given during the year to the subject, the expediting of freight car movements through yards. The Committee has restricted its first progress report to a generalization of the subject with the intention of carrying its study to more specific details.

Iron and Steel Structures (A. R. Wilson, *Chairman*).—The present report consists of a complete revision of the Specifications for Steel Railway Bridges, for fixed spans not exceeding 400 feet in length. This monumental work of revision has engaged the intensive study of the Committee for a period of four or five years. The first specification was adopted in 1903; revisions were made in 1904, 1905, 1906, 1910, 1920, 1923, 1925, 1931. . . . The personnel of the Committee comprises leading railway Bridge Engineers of this and foreign countries, members of faculties of Universities, and bridge fabricators. As an indication of the value of these specifications it is of interest to note that they have been translated into the Spanish language and published under the auspices of the Argentine Republic government. The introductory to the translation stated that these specifications exemplify the best modern practice for steel railway bridges. This document may be considered one of the outstanding achievements of the Association.

Economics of Railway Location (F. R. Layng, *Chairman*).—This Committee has been requested to give a definition for "Rise-and-Fall," and in compliance with that instruction, quotes the definitions given by a number of authorities, and recommends that the following definition be adopted: " 'Rise-and-Fall' is the sum of vertical ascents in rising from a starting point or level to a summit and returning to same point or level, inclusive of all grades on the profile between any two points or termini."

Electricity (W. M. Vandersluis, *Chairman*).—It is the function of this Committee to keep the AREA members informed of the activities of the Electrical Section, and of developments in the application of electricity to railway service. A synopsis is given of the current reports made to the Electrical Section. Among the reports of special interest to Maintenance of Way Engineers are reports on electric heating, application of different types of motors, protection of railroad equipment from danger of fire caused by electric sparks during the transfer of inflammable liquids, illumination, design of indoor and

outdoor substations, and application of corrosion-resisting materials to railroad electrical construction.

Wood Preservation (F. C. Shepherd, *Chairman*).—For the purpose of harmonizing the AREA specifications for Creosote with those of the ASTM and the AWPA, certain revisions are proposed. A number of other changes in the chapter on Wood Preservation are presented for approval. . . . The presentation of service test records of treated ties has been continued. Reports covering special test tracks on a number of roads are presented. . . . The Committee has continued its contact with the Chemical Warfare Service of the U. S. Army in the study of piling used for marine construction. A large amount of valuable information on marine borers is included in the current report. . . . Specifications for Treatment of Air-Seasoned Douglas Fir are presented for approval. . . . The Committee has continued its study of termites and presents interesting material on this subject. . . . A timely and valuable report is that relating to the loss of preservative in treated ties in track due to use of oil-burning weed destroyers. . . . The Committee presents in an interesting manner report on methods of protection of treated materials in the field. . . . A notable report is that relating to service test records of structural timber, including piling. The report includes an interesting tabulation on service test records of structural timber giving outstanding service.

Uniform General Contract Forms (F. L. Nicholson, *Chairman*).—The Form of Agreement for the Purchase of Electrical Energy in Large Volume (such as required for traction purposes), submitted heretofore in preliminary form, has been revised in the light of the comments and suggestions received, and the draft of the completed form is now presented for approval as recommended practice. . . . A Form of Conveyance of Title Granting the Right to Construct and Maintain Buildings over Railway Property has been formulated and is offered for consideration and comments. . . . On the subjects, Form of Agreement for Pipe Lines Crossing Under Railway Tracks, and Form of Agreement for Use of Railway Property by Pipe Lines Paralleling Railway, with special reference to pipe lines carrying high pressure inflammable oils or gas—the Committee decided that one form could be prepared to cover both assignments, and accordingly has prepared a form in collaboration with other committees concerned and with a special committee of the American Petroleum Institute, and now presents the form for approval as recommended practice. . . . A Form of Agreement with Public Authorities for Highway Grade Crossing Elimination or Separation is submitted for information and discussion.

Economics of Railway Operation (J. E. Teal, *Chairman*).—Under the title, economic effect of the new 131-lb. RE rail section on the cost of operation, as compared with the 130-lb. RE section, the Committee has presented an exhaustive analysis to determine whether or not an improvement has been secured. The report is sub-divided into life of rail; effect of wear on life of rail; effect of carbon content upon the life of rail; effect of amount of rolling and rapidity of cooling upon life of rail; effect of stiffness, of width of head; estimated life of the two rail sections; material cost of the two sections; effect of rail upon track maintenance, and upon equipment; economies in cost of tie renewals per mile of main track; effect of rail upon train operation; recapitulation, and under conclusions the Committee states the 131-lb. RE rail section as compared with the 130-lb. section is an improvement by reason of its increased girder strength, resulting in better riding track, with less damage to equipment and track and a consequent lower operating cost; the improvement in the design of the rail head should result in better quality of metal, thus prolonging rail life and decreasing possibility of accidents due to breakage; these factors therefore should result in an appreciable saving without materially increasing investment. . . . A valuable report is submitted on the capacity of steam locomotives (a supplement to the 1933 report); and a preliminary comparison of freight train and yard switching performance for the purpose of noting the effect of operating heavy trains upon yard performance. The report contains numerous diagrams and tables. . . . Another able report is

presented by the Committee on the effect of volume of traffic on railway operating expense, supplemented with a series of tables and diagrams.

Economics of Railway Labor (Lem Adams, *Chairman*).—A review of the report on methods of reducing work-train service, and economies in maintenance of way expenses effected thereby, discloses that intensive studies has been given this subject by the Committee. As a result of its study, the Committee concludes that maintenance of way operations should be carefully planned to reduce the number of work-trains required; by so programming work as to permit it to be done in consecutive order and eliminate duplicate movements; by utilizing spare time of light extra and local trains; by having a thorough understanding by all concerned in the transportation and maintenance departments regarding work to be done and time required to do it; by insuring that locomotives assigned have sufficient power to handle the work; by loading materials in suitable cars; by selection of proper type of cranes for loading and unloading rail and having a properly organized gang experienced in the kind of work being done; by lining up work to be done in consecutive order to avoid backup movements and having sufficient work for a full day's work-train service; by the extended use of motor cars to handle men and materials; by the use of self-propelled equipment wherever suitable by further development and use of off-track equipment. . . . Another excellent report is that of programming of bridge and building work. Suitable forms for accomplishing the desired object are presented. . . . One of the subjects to which this Committee has addressed itself in years past is that of handling railway labor. In one of its earlier reports, typical plans for housing labor were presented. That report contained typical plans for the construction of camp or outfit cars; these plans have been beneficial in bringing about an improvement in the sanitation and comfort of outfit cars for floating gangs. Revision of these earlier plans has been assigned to the Committee, and in line with its instructions, the Committee has presented typical plans for the construction of foreman's car; kitchen and dining car; recreation car; sleeping car, and water and fuel car, and recommends that living conditions of outfit cars be made as comfortable and sanitary in accordance with these general plans as economic conditions permit.

Shops and Locomotive Terminals (J. M. Metcalf, *Chairman*).—At the last annual meeting, a series of conclusions with reference to turntables were presented for approval and which were adopted, with the exception of one conclusion, No. 3, which referred to the method of installation for power-operated turntables. Further study has been given to this feature during the year, and the Committee now presents a revised conclusion for approval. . . . A new subject was assigned to this Committee for study and report, entitled, power plants. This assignment has been interpreted to mean power plant operation, maintenance and recommended capacity at important locations. An interesting report has been prepared along these lines. . . . A valuable contribution is presented on wheel-removing equipment for engine houses. The report deals with the evolution of drop-pit equipment, drop tables, special points of advantage, general requirements, and selection of drop table. . . . Based on replies to a questionnaire, a valuable report has been formulated on the subject of car paint shops.

Rivers and Harbors (W. C. Swartout, *Chairman*).—Additional definitions of terms are presented for criticism. . . . Detailed specifications for the construction of the several types of river bank protection in common use have been formulated and are submitted as information. . . . A valuable report is that describing and illustrating the different forms of protecting wharves by means of fenders. . . . An interesting contribution to the knowledge of the subject is the report on coal and ore piers on the Atlantic and Pacific Coasts and ore docks on the Great Lakes, including description of foundations, facilities and capacities. Reference is made to articles in engineering magazines descriptive of many of these coal and ore docks. . . . The Committee calls attention to the excessive clearance requirements for bridges spanning inland streams which are considered navigable, and states

it is collecting information for use in reporting a formula which can be used as a guide to a proper solution of problems of this character. . . . Intensive study has been given to the subject of cost to the railways for the construction, maintenance and operation of bridges over navigable waterways. The statutes of the United States applicable to navigation and navigable waterways are quoted. From its study of the subject the Committee has set forth a series of principles that in its judgment are equitable and that should govern in providing funds for the construction, maintenance and operation of bridges, including approaches thereto, over navigable waterways.

Standardization (J. C. Irwin, *Chairman*).—It is the function of this Committee to encourage the use of AREA recommended practice, to propose to the Board of Direction projects for national standardization, to maintain contact with standardization bodies, and to keep the Association informed on important matters developed by such contact. The report describes the contact established during the year with the staff of the Federal Coordinator of Transportation, specifically with the Section of Purchases. . . . Subjects recommended for national standardization are listed and their present status set forth. . . . Developments in American Standards Association are reported on, including the plan of transferring to the ASA most of the work heretofore handled by the National Bureau of Standards in the sphere of simplification, commercial standards, safety codes and building codes. . . . A brief memorandum regarding the Canadian Engineering Standards Association activities is included in the report. . . . The standards approved by the ASA in the period September 1, 1932 to September 1, 1933, are listed. . . . The technical projects on which the railway associations are cooperating conclude the report.

Waterproofing of Railway Structures (J. A. Lahmer, *Chairman*).—Principles governing the use of waterproofing or dampproofing of railway structures are submitted as information. . . . A year ago, the Committee presented a specification for membrane waterproofing. This specification is now resubmitted for approval and insertion in the Manual. Only a few minor changes have been made in the previous version for the purpose of simplification and the elimination of a minor inconsistencies.

Maintenance of Way Work Equipment (C. R. Knowles, *Chairman*). The Committee submits an interesting report on the adaptability of air and electric driven tools in maintenance of way work, the current contribution dealing principally with track grinders. Various types are illustrated in the report. . . . An exhaustive report on snow-melting devices was presented last year; the current report supplements the information previously submitted. The Committee concludes that under proper conditions, snow-melting devices are an aid in facilitating train operation and reducing maintenance expenses. . . . Supplementing its report of last year on the use and adaptability of track type tractors in maintenance of way work, the current report describes specific operations of such tractors used in conjunction with certain specially designed attachments, which adapt the machine to various uses. The report contains some interesting illustrations. A scoring sheet is shown for the purpose of providing a basis for the logical and systematic comparison of tractors of various makes and aid in the selection of a particular machine for purchase. . . . A most practical and interesting report is that on the use of weed destroying equipment, including horse-drawn and power mowers operating both on and off the track. A table indicating weed destroying equipment and cost data for operation is included in the report. Various types of weed burners are illustrated. . . . A comprehensive report is submitted on track welding equipment, both oxy-acetylene and electric arc. The two types are described and illustrated. . . . The Committee offers another valuable report on the use and maintenance of paint spraying equipment, with outline of typical organization for various classes of work. An interesting supplement to this report is a monograph on the hazard of spray painting. . . . The report concludes with an additional contribution to its previous report on the organization for the use and maintenance of ballast cleaning machines and con-

ditions under which each particular type may be used. Developments in this field since the former report was rendered are reported on and the new types of cleaning units described.

Clearances (A. R. Wilson, *Chairman*).—An outline diagram of proposed ARA standard box car is submitted for approval. This clearance diagram continues the series that the Committee will present from time to time supplementing those previously adopted. It is planned to eventually assemble all clearance diagrams in one place in the Manual for the guidance of those having need for this important information.

Stresses in Railroad Track (Dr. A. N. Talbot, *Chairman*).—The sixth progress report contains chapters on laboratory tests of Rail-Joints, tests of Rail-Joints on the Pennsylvania Railroad, tests of Rail-Joints on the Chesapeake and Ohio Railway, track depression and rail stresses in tests on the Chesapeake & Ohio Railway, tests of GEO track on the Missouri Pacific Railroad, discussion of tests of Rail-Joints and discussion of tests of track. . . . The work reported involves two general lines of tests, (1) a continuation of the investigation of the rail-joint reported in the Fifth Progress Report, and (2) a study of the general properties and quality of track as related to the stiffness of the rail support and to the uniformity or variability of the play or vertical movement between rail and tie and between tie and its support on the ballast bed upon the application of load. The investigation of the rail-joint has included laboratory tests of several forms of rail-joints to determine characteristics of their action in resisting the bending moments produced by loads, both through an analytical treatment and by a study of the tests themselves. Study has been given to the action of a joint bar as a girder, to the magnitude and position of the supporting reactions at the bottom fishing surface, and to the play between rail and bar (small or large) by reason of lack of fit, and to the corresponding increase in the deflection of the rail-joint. The conditions of the track which affect the development of moment in the rail-joint and the corresponding effectiveness of the joint as a continuation of the rail as a girder have been considered. The angle bar and the symmetrical type of bar have been compared in relation to their usefulness as joint bars. Tests were made on rail-joints in track which have related their behavior in track to the information obtained in the laboratory tests. An important set of tests on rail-joints in track was made with an electric locomotive running at various speeds up to 90 miles per hour. These tests gave information on the stresses developed at the higher speeds as compared with those found at low speeds. The changes in tension in the joint bolts during the passage of the locomotive wheels were also measured. The effect of various conditions of the joint itself, such as tightness or looseness of bolts, fit or play between rail and joint bar, and condition of tie support, was also investigated.

The President:—You have heard the reports of the Secretary and Treasurer. What is your pleasure?

Mr. D. J. Brumley (Illinois Central):—I move the approval of the reports of the Secretary and Treasurer.

Mr. Louis Yager (Northern Pacific):—I second the motion.

The President:—It has been moved and seconded that the reports of the Secretary and Treasurer be approved. All in favor say "aye"; contrary. It is carried and so ordered.

This thirteenth day of March is an occasion that our Secretary no doubt always remembers. He has been with us for thirty-five years, about thirty years of which he has been filling the position of Secretary. Today he is seventy-four years of age. I will ask the convention to stand in his honor.

The President:—The privileges of the floor are extended to visiting railway officials who are not members of the Association, to professors in colleges, as well as any members of the Federal Coordinator's staff that may be present, and they are invited to take part in the discussion of subjects in which they are interested.

The Chair would especially urge the newer and younger members to actively participate in the discussion on the floor. As the older members retire, it is necessary that we have the younger element come to the front and fill up the gap. These new members undoubtedly have views and opinions on the subjects that will be presented, and we would be glad to have their experience and comments.

In the Secretary's report reference was made to a number of deceased members. I will ask that we stand in silence for a moment in their respect.

(The convention arose and stood in silent tribute to the memories of the deceased members.)

The next order of business is the consideration and action of the Standing and Special Committees. As the Committees are called, they will please come to the platform. The first is the Committee on Uniform General Contract Forms. The Committee will please come forward.

The report will be presented by Mr. F. L. Nicholson, Chief Engineer, Norfolk Southern Railway, the Chairman of the Committee.

(For Report, see pp. 309–332.)

The President:—The second report is that of the Committee on Yards and Terminals. Mr. M. J. J. Harrison, General Scale Inspector, Pennsylvania Railroad, is Chairman of the Committee and will please present the report.

(For Report, see pp. 419–472.)

The President:—The next report is that of the Committee on Rules and Organization. Mr. E. H. Barnhart, Assistant Division Engineer, Baltimore & Ohio Railroad, is Chairman, and will tell you what action is desired.

(For Report, see pp. 521–528.)

The President:—The report of the Committee on Records and Accounts will be presented to you by its Chairman, Mr. C. C. Haire, Engineer of Capital Expenditures, Illinois Central System.

(For Report, see pp. 579–620.)

The President:—Mr. Geo. S. Fanning, Chief Engineer, Erie Railroad, Chairman of the Committee on Roadway, will please present the report to you.

(For Report, see pp. 347–402.)

AFTERNOON SESSION

The President:—The first report on this afternoon's program is that of the Special Committee on Clearances. Mr. A. R. Wilson, Engineer Bridges and Buildings, Pennsylvania Railroad, is Chairman of the Committee.

(For Report, see page 675.)

The President:—The next report is that of the Committee on Ballast. In the absence of the Chairman and Vice-Chairman, I will ask Mr. A. D. Kennedy, Assistant Engineer of the Santa Fe, to present the report.

(For Report, see pp. 663–770.)

The President:—The report of the Committee on Track will be handled by Mr. C. J. Geyer, Assistant to Vice-President, Chesapeake & Ohio Railway.

(For Report, see pp. 923–955.)

Vice-President John E. Armstrong:—The report of the Buildings Committee will be presented by its Chairman, Mr. G. A. Rodman, General Supervisor Bridges and Buildings, New York, New Haven & Hartford Railroad.

(For Report, see pp. 529–559.)

Vice-President John E. Armstrong:—The next report is that of the Committee on Shops and Locomotive Terminals. Mr. J. M. Metcalf, Assistant Chief Engineer, Missouri–Kansas–Texas Lines, is Chairman of the Committee.

(For Report, see pp. 403–417.)

Vice-President John E. Armstrong:—Our next report is the Committee on Maintenance of Way Work Equipment. Mr. C. R. Knowles, Superintendent Water Service, Illinois Central System, is Chairman, and will present the report to you.

(For Report, see pp. 473–520.)

The President:—The report of the Committee on Waterproofing Railway Structures will be presented by its Chairman, Mr. J. A. Lahmer, Senior Assistant Engineer, Missouri Pacific Railroad.

(For Report, see pp. 699–712.)

EVENING SESSION

The President:—The first report this evening will be that of the Committee on Rail. Mr. Earl Stimson, Chief Engineer Maintenance, Baltimore & Ohio Railroad, is Chairman, and will please present the report.

(For Report, see pp. 829–878.)

The President:—The next report is that of the Special Committee on Stresses in Railroad Track. The report will be presented by Dr. A. N. Talbot, Professor Emeritus of the University of Illinois, Chairman. Dr. Talbot's report will be accompanied with lantern slides.

(For Report, see Bulletin 358.)

WEDNESDAY, MARCH 14, 1934

MORNING SESSION

The President:—The first report this morning is that of the Committee on Ties. Mr. W. J. Burton, Assistant to Chief Engineer, Missouri Pacific Railroad, is Chairman, and will tell you what action is desired on this report.

(For Report, see pp. 779–828.)

The President:—The next Committee to report is that on Wood Preservation. Mr. F. C. Shepherd, Consulting Engineer of the Boston & Maine, is Chairman.

(For Report, see pp. 713–777.)

The President:—The Committee on Water Service and Sanitation report will be presented to you by the Chairman, Mr. R. C. Bardwell, Superintendent Water Supply, Chesapeake & Ohio Railway.

(For Report, see pp. 621–643.)

Vice-President John E. Armstrong:—The report of Committee X—Signals and Interlocking will be presented to you by Mr. P. M. Gault, Signal Engineer, Missouri Pacific Lines, the Chairman.

(For Report, see pp. 333–341.)

Vice-President John E. Armstrong:—The next Committee to report is Committee XVIII—Electricity. Mr. W. M. Vandersluis, General Superintendent Telegraph and Signals, Illinois Central System, is Chairman, and will tell you what action is desired by the convention.

(For Report, see pp. 343–345.)

Vice-President John E. Armstrong:—The report of the Committee on Wooden Bridges and Trestles will be presented to you by its Chairman, Col. H. Austill, Bridge Engineer, Mobile & Ohio Railroad.

(For Report, see pp. 997–1009.)

The President:—The report of the Committee on Masonry will be presented by its Chairman, Mr. Meyer Hirschthal, Concrete Engineer, Delaware, Lackawanna & Western Railroad.

(For Report, see pp. 957–996.)

AFTERNOON SESSION

The President:—The report of Committee IX—Grade Crossings will be presented to you by its Chairman, Mr. J. G. Brennan, Engineer of Grade Crossings, New York Central.

(For Report, see pp. 561–577.)

The President:—Committee XXV—Rivers and Harbors will be presented by its Chairman, Mr. W. C. Swartout, Assistant Engineer, Missouri Pacific Railroad.

(For Report, see pp. 677–697.)

The President:—The next report is that of the Committee on Iron and Steel Structures. Mr. A. R. Wilson, Engineer Bridges and Buildings of the Pennsylvania Railroad, is Chairman, and will tell you about the report.

(For Report, see pp. 1011–1064.)

Vice-President Robert H. Ford:—The next report is that of the Committee on Economics of Railway Location. Mr. F. R. Layng, Chief Engineer, Bessemer & Lake Erie Railroad, is Chairman.

(For Report, see pp. 671–674.)

Vice-President Robert H. Ford:—The next report is that of the Committee on Economics of Railway Operation. Mr. J. E. Teal, Special Engineer—Operation, Chesapeake & Ohio Railway, is Chairman, and will tell you what action is desired by the convention.

(For Report, see pp. 879–922.)

Vice-President Robert H. Ford:—The report of the Committee on Economics of Railway Labor will be presented to you by its Chairman, Mr. Lem Adams, Chief Engineer, Oxweld Railroad Service Company.

(For Report, see pp. 645–662.)

Vice-President Robert H. Ford:—The last report this afternoon is that on Standardization. Mr. J. C. Irwin, Valuation Engineer, Boston & Albany Railroad, is Chairman, and will give you a synopsis of the report.

(For Report, see pp. 1065–1077.)

The President:—This completes the consideration of Committee reports.

The next order of business is New Business. Has anyone anything to offer under that heading?

Mr. Edwin F. Wendt (Consulting Engineer):—I desire to offer a resolution.

"The American Railway Engineering Association, in convention assembled, expresses its hearty appreciation to Dr. A. A. Potter, Dean of Engineering, Purdue University, for his most excellent and constructive address at the luncheon of the Association on Wednesday, March 14."

I move the adoption of this resolution.

The President:—You have heard the resolution. All those in favor will say "aye"; contrary. It is carried.

Is there any further new business? The result of the attendance this year is 510 members and 198 visitors, a total of 708, as against 395 members and 209 visitors, a total of 604, in 1933.

If there is no further new business, the Secretary will announce the result of the election of officers for the ensuing year.

Secretary E. H. Fritch: Report of the Tellers. "We, the Committee of Tellers, report the following as the result of the count of the ballots:

For President:

John E. Armstrong	937 votes

For Vice-President:

A. R. Wilson	931 votes
S. S. Roberts	1 vote

For Secretary:

E. H. Fritch	937 votes

For Treasurer:

A. F. Blaess	927 votes

For Directors (Three to be elected):

R. C. Bardwell	395 votes
W. J. Burton	368 votes
E. L. Crugar	355 votes
F. L. C. Bond	350 votes
W. H. Penfield	336 votes
J. A. Peabody	298 votes
C. C. Williams	281 votes
R. S. Belcher	254 votes
C. A. Wilson	186 votes

(The three elected are:—R. C. Bardwell, W. J. Burton, E. L. Crugar.)

For Members Nominating Committee (Five to be elected):

W. S. Burnett	554 votes
E. H. Barnhart	538 votes
H. A. Dixon	526 votes
A. A. Miller	521 votes
W. A. Murray	485 votes
Robert Faries	468 votes
J. M. Farrin	450 votes
Wm. Michel	416 votes
C. B. Stanton	395 votes
John Foley	252 votes
J. A. Heaman	1 vote

(The five elected are:—W. S. Burnett, E. H. Barnhart, H. A. Dixon, A. A. Miller, W. A. Murray.)

Signed by the Committee of Tellers, Ben B. Shaw, Chairman.

The President:—It is customary to present to the outgoing Past-President a medallion as a token of our esteem and regard. Mr. W. D. Faucette is the Senior Past-President and is the recipient of the medal this year. Mr. Faucette is unavoidably absent and, with your approval, it will be presented to him at an opportune time.

Mr. J. C. Irwin (Boston & Albany):—President Wiltsee, in times of stress a strong man always arises with the ability to overcome all obstacles.

When you were started by this Association on the direct path to the presidency, it was realized that you had the qualities to overcome obstacles and deliver the goods. During the year of your administration there have been very many unusual problems, but you have met them in every case with prompt action, sound judgment and outstanding ability.

I have the honor, Sir, to act for the Association in presenting to you, in the form of a resolution and permanent record, this plaque as a testimonial from the Association in recognition of your distinguished services to the Association. I now present this resolution, and, in presenting it, I also second the resolution as follows:

"The American Railway Engineering Association records its grateful appreciation to WILLIAM P. WILTSEE for valuable services rendered as President in 1933–34. He contributed freely and generously of his time and ability to the solution of important problems arising during his term as President, and his sound judgment and high-minded conception of his responsibility materially enhanced the prestige and achievement of the Association."

Mr. Wiltsee, we present this to you (Applause).

I call for a rising vote.

(The audience arose and applauded.)

Mr. J. C. Irwin:—President Wiltsee, that is the rising vote approving the resolution.

The President:—Mr. Irwin and Gentlemen: I thank you very much. I do not have words to express my feelings in this matter. It is a time and a place where a man realizes whether or not he has been a failure. Whatever success there may have been during this year I attribute very much to our Committees and to our Board of Direction who have assisted me in every way, in granting me such powers as they did, and I could not help but carry on the work successfully with such cooperation.

Thank you, gentlemen (Applause).

If there is no further business before the meeting, the Chair will ask Past-Presidents Brumley and Fairbairn to escort the President-Elect to the platform.

(President-Elect Armstrong was escorted to the platform. The audience arose and applauded.)

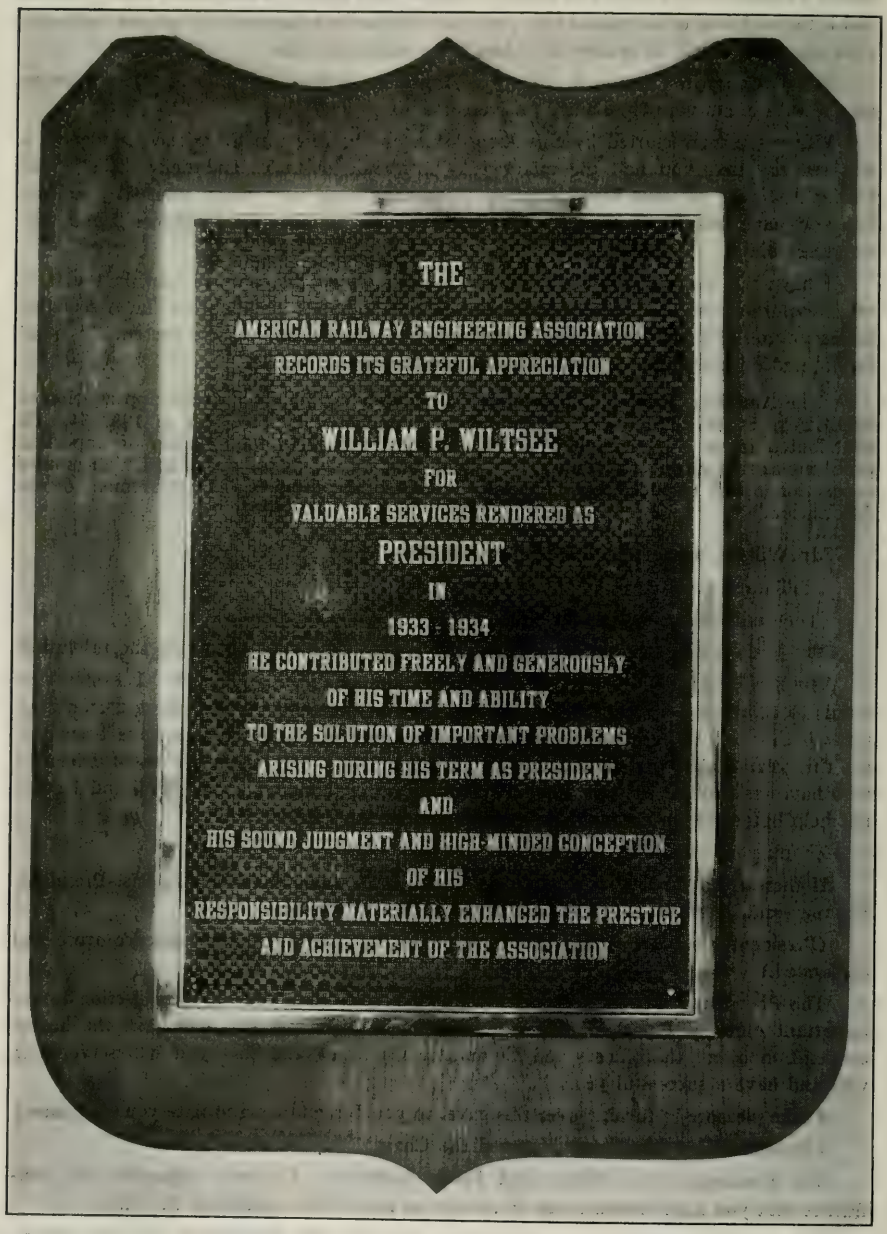
The President:—Mr. Armstrong, I want to congratulate you on your election to the important office of President of this Association. I am sure you will have the hearty cooperation of all the officers and Committee Chairmen and that you will serve them well and have a successful year.

I take pleasure in turning over this gavel to you, Sir, and congratulate you (Applause.)

(President-Elect Armstrong assumed the Chair.)

The President:—Mr. Wiltsee and Fellow-Members: I greatly appreciate the confidence that you have shown in me in advancing me to this position at this time.

The past few years have not been easy years for this Association, and the coming year may prove to be, in many respects, equally difficult. I am looking forward, however, without a qualm. With such support as the officers, Directors, Committees and


THE
AMERICAN RAILWAY ENGINEERING ASSOCIATION
RECORDS ITS GRATEFUL APPRECIATION
TO
WILLIAM P. WILTSEE
FOR
VALUABLE SERVICES RENDERED AS
PRESIDENT
IN
1933 - 1934
HE CONTRIBUTED FREELY AND GENEROUSLY
OF HIS TIME AND ABILITY
TO THE SOLUTION OF IMPORTANT PROBLEMS
ARISING DURING HIS TERM AS PRESIDENT
AND
HIS SOUND JUDGMENT AND HIGH-MINDED CONCEPTION
OF HIS
RESPONSIBILITY MATERIALLY ENHANCED THE PRESTIGE
AND ACHIEVEMENT OF THE ASSOCIATION

members of this Association have so continuously and freely given in the past, we have no reason to fear for the future.

I am deeply conscious of the honor you have conferred upon me in advancing me to this high position, and I shall endeavor to merit this honor by serving you as you would be served, and doing everything in my power to maintain the prestige of the American Railway Engineering Association. Thank you (Applause).

Is there any further business to come before this meeting? If not, I declare the Thirty-fifth Annual Convention of the American Railway Engineering Association adjourned.

E. H. Fritch

Secretary.

RESEARCH AS APPLIED TO RAILROADING

By Dr. A. A. POTTER, Dean of Engineering and Director Engineering Experiment Station, Purdue University; Past-President A.S.M.E.

The railroads of this country deserve major credit for our national unity; great distances separate the political units of our government and its solidarity depends upon effective, dependable, safe and adequate transportation facilities. A democratic government, like the U.S.A., could not have been maintained 200 years ago; no doubt the locomotive did more to keep our forty-eight states together than has all special legislation in Washington and at the State capitals. The large geographic area of this country, the absence of economic barriers between our states and the resulting free interchange of goods and services, make transportation of vital importance to our commerce and industry.

The past record of American railroading needs no defense and its indispensability in connection with our future social and economic progress cannot be questioned. Railroad management has been fully appreciative of the fact that operation and maintenance of railway equipment require constant study and vigilance. During the period from 1923 to 1933 inclusive the American Railway Association has expended for research, experimentation, testing and standardization nearly six and three-quarter million dollars; additional sums, the total of which it is difficult to estimate, have been expended for testing, development and research by individual railroads and by manufacturers of equipment. However, one hears too frequently implications that the railroad companies have stood still and have neglected to make full use of new science to insure their future programs with a degree of certainty. The February 1934 issue of Mining and Metallurgy, in discussing the publication of the American Railway Association entitled "The American Railroad in Laboratory," states that the railroads have carried on experimentation but not research, adding that "the book is a mute evidence of the fact that its sponsors have no true conception of scientific research in its modern aspect."

The questions before us then are: first, what is research; second, are the railroads constantly alert to the new scientific developments which come from the outside; and third, how can railroading make greater use of basic scientific knowledge to improve service, reduce costs and increase earnings?

What is research? Research is a fact-finding agency. It has as its aim the orderly search for something hitherto unknown by the employment of facts. To most people research means search for new knowledge in the fields of biology, physics, chemistry or in applied science such as engineering, when this involves the use of test tubes, delicate instruments and special machines under fully isolated conditions.

The search for truth by the fact-finding method, however, applies to human as well as to material problems; to advertising, marketing and personnel matters as well as to development, design, manufacturing, maintenance and service; to psychology, economics, sociology, and politics as well as to biology, physics, chemistry and engineering. Fact-finding methods and not merely opinions should prove helpful in solving problems of finance and government as well as questions pertaining to physical sciences and technology. No clear-cut differentiation can be drawn between pure scientific and engineering research, although the latter is generally concerned with results of immediate economic value. The difference between development and research is also far from distinct. Development usually follows basic research if a marketable product is the aim, but development must involve fact-finding technique through experimentation and testing.

Address before the American Railway Engineering Association, March 14, 1934.

All types of scientific research, whether pure or applied, require testing and experimentation.

Thus it matters little whether the fact-finding activities of the railroads are called research or development or testing or experimentation, provided they are useful in securing facts to guide decisions with reference to equipment purchase and maintenance as well as for the improvement of operation and service. It is not clear, however, whether the railroads have utilized research to explore new opportunities or were merely satisfied to employ experimentation and testing to improve present devices and methods. An analysis of the railroad research program during the past 40 years leads one to question as to whether the railroads have given sufficient attention to new ideas and have been satisfied to devote their creative efforts to the improvement of existing equipment. Statements have even been made that the present condition of the railroads would have been much better had they explored absolutely new paths and had they watched more carefully development from the outside.

Accordingly, it may be well to appraise the activities of the fact-finding agencies in connection with railroading. These include: Equipment manufacturers, individual railroads and the American Railway Association.

The manufacturing industry of this country supplies to the railroads the materials, structures and equipment. Most of the equipment manufacturers who serve the railroads also sell materials and equipment to other industries; thus the gains which these equipment companies have secured through research have been transmitted to the railroads as well as to the other customers of the manufacturing industry. The equipment manufacturers have greatly contributed to the increased output of American railroads per dollar of investment and per employee by improvements in plant. While some of the leading European railroads build two-thirds or more of their locomotives in their own shops, the majority of American locomotives have been built by manufacturing companies which have specialized in locomotive design and construction. The marked increase during the past decade in the power output per driving axle and the reduction during the same period of about twenty per cent in fuel consumption per passenger-train car mile and of nearly thirty per cent in fuel per ton-mile of freight hauled are an indication of the progress made by American locomotive builders and by manufacturers of locomotive auxiliary and accessory equipment. Paralleling the improvements in steam locomotives one finds great strides in electric locomotive design as well as in internal-combustion-driven rail cars and Diesel-electric locomotives for special service. Apparently the manufacturers of car equipment are also appreciative of the contributions of research and are saving car weight by the use of welded steel construction and light weight materials. Manufacturers of equipment and supplies have also expended large sums to insure improved air brakes, better car cushioning, more effective bearings and superior lubrication. Time will not permit to discuss in detail the improvements made by manufacturers individually and cooperatively in car trucks and parts, car wheels, automatic couplers, draft gears, or in special equipment for locomotive repairs and for the upkeep of tracks and structures, or in signaling; these are all greatly contributing to the plant efficiency and safety of travel, while reducing train delays.

The contributions of the equipment manufacturers to new knowledge are many and most pertinent to advancement in railroading, but there is a feeling in certain quarters that research and development by equipment companies are guided largely by their own ideas of the railroads' needs instead of benefiting by their customers' definite recommendation of their requirements. Statements have also been made that equipment manufacturers devote more energy to the pointing out of faults in each other's products than to the improvement of their own; also that railroads consider competition between manu-

facturers of equipment as sufficient guarantee of a superior product. To what extent these statements are true is difficult to answer, but a closer coordination of the research activities of the equipment companies and those of the railroads should aid in avoiding the above-mentioned practices, if they exist.

There is apparently no complete published record of the testing and other research facilities of individual railroads. I do know that the larger railroads do not accept new designs of equipment without special tests, unless such improvements have been approved by the American Railway Association. Most railroads maintain their own test department and have sufficient laboratory facilities for physical and chemical tests. The laboratories of the Pennsylvania Railroad at Altoona, the New York Central Laboratory at West Albany, the Santa Fe Test Department at Topeka, and those of other important lines are utilized for carrying on some experimentation of high order as well as testing. Individual railroads should have considerable credit for the recent advance in air-conditioning of passenger cars, pre-cooling of sleeping cars, the use of improved types of bearings, streamlining and light-weight trains, and improved locomotive performance. However, the creative efforts of the individual railroads are evidently not definitely coordinated, resulting in considerable duplication.

Accurate information is available of the contributions of the American Railway Association through its eight divisions, bureaus and special committees. During the past eleven years (1923–1933 inclusive) more than one-half of the fact-finding expenditures of this association, or over three and three-quarter million dollars, were devoted to the Mechanical Division; the major portion of these expenditures was concerned with the investigations pertaining to air brakes, draft gears and automatic train connectors. The Mechanical Division has had a part-time director of research for a number of years, but the other divisions have depended entirely upon committees. Even in the Mechanical Division the part-time director was concerned only with a portion of the fact-finding activities of this Division, the remainder being also directed by committees. While the devotion, industry and ability of the members of these committees cannot be questioned, it is evident that the men who compose the committees of the different divisions are mainly concerned with operation, are only rarely research specialists and are usually too busy with their regular duties to devote the time necessary to direct and to coordinate research. Members of committees are usually selected because of geographical distribution, or availability, and even favoritism has been known to guide their choice rather than specialized knowledge or outstanding research ability. Furthermore, these committees have been usually appointed to handle routine matters, thus leaving the research problem with little if any direction. Then again the committees of the American Railway Association are appointed to remedy existing troubles and are rarely concerned with new problems or novel methods, and are not in a position to keep the railroads fully informed of developments which take place outside of railroading. Apparently, the American Railway Association coordinates the research activities in railroading only to some extent but not entirely. While the present part-time director is in touch with some of the mechanical phases of railway research, he has nothing to do in coordinating the fact-finding activities of the other divisions of the American Railway Association, of the individual railroads or of the equipment manufacturers.

Great credit should be given to the Engineering Division of the American Railway Association for the present standard rail sections and for basic investigations on rails, grade crossings, preservative treatment of ties, transverse fissure rail failures, and stresses in railroad track. However, a full-time director of research should prove most helpful in bringing about more effective cooperation between all the Divisions and Bureaus of the A.R.A., as well as those of the individual railroads. Such a director, if supplied with

an adequate and capable staff, may also be able to bring about a closer cooperation between the railroads and the equipment manufacturers, and would supplement their efforts. Centralized and authoritative research direction should prove helpful in encouraging investigations, on a larger scale than is possible with the present committee system, not only in basic science, but also business and social research.

While American railroads must be credited with experimentation, standardization and practical research of a high order, which has resulted in service, the quality of which no other railroad system in the world equals, it is the opinion of those who are keenly interested in the future of American railroading that even greater accomplishments might be possible if the railroad industry gave greater attention to basic scientific and business research, under competent centralized direction, and mutually supported by all the railroads of this country.

Effective centralized direction requires a director, assisted by a trained research staff, whose only duty is to undertake new problems for the benefit of all of the railroads of the country. This research should be carried on in a laboratory centrally located. The campus of an engineering college may prove a suitable place for building such a laboratory, as it would then be in an atmosphere which is sympathetic to research. The central research laboratory at an educational institution may prove also advantageous to the railroads from a financial standpoint, as to a considerable extent the facilities of the engineering college in staff, laboratory equipment and library could be utilized. The U.S. Forest Products Laboratory at the University of Wisconsin and the Tanner's Laboratory at the University of Cincinnati are examples of centralized research laboratories at educational institutions.

A central research laboratory under competent direction would not invade the field of the individual railroad test department and should supplement the laboratories of equipment companies. Such centralized direction would, however, definitely correlate all of the valuable research activities of the railroads and of the manufacturers of equipment and should make possible the pursuit of many basic transportation studies which are now difficult to undertake due to the competition between the railroads themselves as well as between the railroads and other modes of transportation. A centralized railroad research agency should also handle patent matters referred to it by railroads. Research to be most productive in revealing new possibilities and in forecasting future trends must be continuous, and cannot be started and stopped on short notice. It takes many years to build up a high-grade research organization and only centralized direction, a central laboratory and a long-time research program may be expected to yield permanent results.

With reference to the types of problems in the interest of railroading, which central research direction may undertake, consideration may well be given to better riding qualities, improved ventilation, greater cleanliness and reduction of noise for passenger cars, elimination of shocks in train handling, mathematical study of springs on vehicles, dynamic balancing of more powerful high-speed motive power, improved prime movers of superior fuel economy, better light-metal alloys, new uses and applications of the findings of science, and experimentation with types of equipment leading to different operating procedure. Central direction of research, if properly financed, may hasten the solution of such problems as the transverse fissure rail failures by extensive studies under controlled conditions. However, research should not be satisfied merely to remedy existing difficulties, but should constantly strive to develop new ideas, better devices and improved methods, while keeping fully informed of the new facts revealed by other industries. Research should back away from things at hand and should take a view of transportation as a whole.

Central direction of research should not limit its activities to science and technology, but should encompass all fact-finding matters, including business and human research problems. Examples of non-technical problems are basis for rates and fares, traffic, railroad financing, wage scales and personnel matters affecting employees, operating cost studies, public relations, with particular reference to favorable impression upon users of service, the coordination of all types of transportation, and similar social and economic problems of interest to railroading.

To be of maximum value, all research activities in railroading must be coordinated with one major objective in view; an objective which keeps constantly in mind the place of the railroad in the transportation fabric of the country. All past studies, technical, social and economic, must be carefully analyzed, and new developments planned to suit the constantly changing conditions, but with the main objective in mind.

The cost of centralized research should be small for sometime, as it will require several years to build up a proper research staff. Existing facilities at some centrally located engineering college could be utilized advantageously, either temporarily or permanently, and the program enlarged as conditions merit greater expenditures. No doubt, the present duplication of research effort and the committee system of supervision involve considerable waste, the elimination of which should result in savings which should be sufficient to start a high-grade central research laboratory for American railroads. There is also a possibility that a proper coordination of all railroad research work would result in less misdirected effort by equipment manufacturers for which the railroads have to pay in the long run.

In the earlier part of my paper I stated that the railroads have expended cooperatively, through the American Railway Association, a total of nearly six and three-quarter million dollars during the past eleven years for research, routine testing and standardization. Of this more than two and one-quarter million were used for investigation of power air brakes, leaving less than four and one-half million dollars for the other types of research, testing and standardization, with railway operating revenues of nearly 53 billion dollars during the period from 1923 to 1933. This means that the railroads have devoted collectively only about one-hundredth of one per cent of their operating income for the creation of new knowledge, as compared with expenditures of one to four per cent for research in the case of progressive industries. The American Telephone and Telegraph Company reports an average annual expenditure of $8,700,000 for research, even during the past four years of depression, with a gross revenue of only about one billion dollars per year; the Aluminum company of America has been devoting one to four per cent of its gross income for research; and the DuPont, one and one-half to four per cent of its net income; these industries consider expenditures for research as the insurance which their companies must take out in order that their products and services will not only continue to show improvement year by year, but be more adaptable to the changing needs and desires of the people served. Any industry which does not take advantage of new knowledge and is not constantly on the lookout for new developments, is bound to lose in its competition for sales or services.

In advocating more effective centralized research and greater expenditures for the creation of new knowledge, I am not unmindful of the splendid contributions of the American Railway Association, the equipment manufacturers and the individual railroads. So far as they have gone the results have been excellent, but railroad research, particularly of the basic type, has not been carried out on a scale which its importance for railroading deserves; too large a proportion of past research efforts have been directed to old problems and too little to those of the future. Intelligent anticipation of a new problem will often change the course of events and may forestall unfavorable develop-

ments from the outside. A well-balanced and energetic program of basic transportation research will pay big dividends in the practical results secured.

Sir Harold Hartley calls research "the door to to-morrow." Let us hope that greater attention to railroad research will result in a to-morrow which will definitely improve the financial condition of the railroads, will enhance their place in the transportation fabric of this country, and will benefit the public by cheaper, safer and better rail transportation. In the past Government regulation has been responsible at least in part for the failure of railroads to make long-time plans. The many uncertainties which have surrounded railroad financing and management have made it of necessity a hand-to-mouth industry. Let us hope that the forward-looking program of the United States Government will remove some of the past handicaps and will fully justify American railroads in utilizing more research in long-time planning.

In making the above statements I am giving you only my own frank views of the subject of research as applied to railroading and not those of the Committee on Railroads of the Science Advisory Board, of which I have the honor of being a member. This committee in accordance with instructions by Coordinator Eastman, was formed "to cooperate with a committee of railroad executives in an effort to assist the railroads to secure the maximum benefits in utilizing modern science and engineering." It has been my privilege to attend all of the meetings of this joint committee of railroad executives and representatives of the Science Advisory Board, and I can assure you that there is a very fine spirit of helpfulness and of cooperation. The studies of this joint committee have not progressed sufficiently to merit conclusions or recommendations. It is evident, however, that the deliberations thus far have been definitely in the interest of the railroads.

My own long connection with a University, which for over forty years has cooperated most effectively with the railroads of this country and my intimate association with your problems, lead me to assure you of my sincere desire to assist in the return of prosperity to that indispensible and safest means of transportation which you represent.

I feel that research is the "Fountain of Youth" which will aid you in enhancing the place of railroading in the transportation fabric of America. Accordingly, I recommend to you that you make greater use of research in guiding your decisions, that you keep fully informed of new developments outside of your industry, that your experimentation be concerned not merely with improvements in existing equipment, but also with the exploration of new paths, that you take a view of the transportation system as a whole, and that you coordinate all fact-finding activities for rail transportation through a central research laboratory staffed with individuals who are skilled in the creation of new knowledge.

COMMITTEE REPORTS

Sixth Progress Report

SPECIAL COMMITTEE ON STRESSES IN RAILROAD TRACK

1933

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SIXTH PROGRESS REPORT OF THE SPECIAL COMMITTEE ON STRESSES IN TRACK

Arthur N. Talbot, *Chairman;*
C. B. Bronson,
John Brunner,
W. J. Burton,
Chas. S. Churchill,
W. C. Cushing,
Robert Faries,
C. W. Gennett,
H. E. Hale,
J. B. Jenkins,
Geo. W. Kittredge,
P. M. LaBach,
C. G. E. Larsson,
John V. Neubert,
J. de N. Macomb,
W. M. Dawley, *Vice-Chairman;*
G. J. Ray,
Albert Reichmann,
H. R. Safford,
Earl Stimson,
F. E. Turneaure,
J. E. Willoughby,
Committee.

To the American Railway Engineering Association:

The Special Committee on Stresses in Track herewith presents its sixth progress report.

I. INTRODUCTION

1. **Preliminary.**—Since its organization in 1914 this Committee has been cooperating with the Special Committee to Report on Stresses in Railroad Track of the American Society of Civil Engineers, the membership of the two committees being almost identical, and the work has been carried on as one committee. This report is presented simultaneously to the two societies and to the American Railway Association, which has furnished financial support and has otherwise cooperated in the work of the investigation. By this continuing organization, the Joint Committee has been able to outline a constructive program, carry out field and laboratory tests, and interpret results in a coordinated way. Five progress reports have been published descriptive of the investigation and its results.

The work herein reported involves two general lines of tests, (1) a continuation of the investigation of the rail-joint reported in the Fifth Progress Report, and (2) a study of the general properties and quality of track as related to the stiffness of the rail support and to the uniformity or variability of the play or vertical movement between rail and tie and between tie and its support on the ballast bed upon the application of load. The investigation of the rail-joint has included laboratory tests of several forms of rail-joints to determine characteristics of their action in resisting the bending moments produced by loads, both through an analytical treatment and by a study of the tests themselves. Study has been given to the action of a joint bar as a girder, to the magnitude of the pressure or load applied on the top fishing surface of the bar by the two rails near their ends and to the position of this load, to the magnitude and position of the supporting reactions at the bottom fishing surface, and to the play between rail and bar (small or large) by reason of lack of fit, and to the corresponding increase in the deflection of the rail-joint. The conditions of the track which affect the development of moment in the rail-joint and the corresponding effectiveness of the joint as a continuation of the rail as a girder have been considered. The angle bar and the symmetrical type of bar have been compared in relation to their usefulness as joint bars. Tests were made on rail-joints in track which have related their behavior in track to the information obtained in the laboratory tests. An important set of tests on rail-joints in track was made with an electric locomotive running at various speeds up to 90 miles per hour. These tests

gave information on the stresses developed at the higher speeds as compared with those found at low speeds. The changes in tension in the joint bolts during the passage of the locomotive wheels were also measured. The effect of various conditions of the joint itself, such as tightness or looseness of bolts, fit or play between rail and joint bar, and condition of tie support, was also investigated.

In the tests of track the effect of various conditions in the track was observed. The differences in the stiffness of the rail support were measured—changes from tie to tie, from one stretch of track to another on the same road, and for different forms of track construction. In particular, the effect of the variability of play between rail and tie and between tie and its bed and the nature and general distribution of the irregularities were investigated and discussed as bearing on variability in the stresses in the rail and in the distribution and magnitude and irregularity of the pressures on the ties and on the ballast beneath them. Information is given on the action of stretches of GEO track with reference to uniformity of stresses in rail, extent of play between rail and tie support, and evenness of bearing of rail on tie-plate and tie-plate on tie.

In the general discussion of rail-joints the functions and the actions of the rail-joint are reviewed, the lateral springing action of joint bars is discussed and the matter of the desirable bolt tension and of fit and limit of play of joint bars is considered. In the miscellaneous remarks on the rail-joint discussion is presented on the shape of the section, on the fit between bar and rail, and on the desirable longitudinal form of the bar (involving controlling the position of the load and reaction bearings between rail and bar), and also on the size and spacing of joint bolts and the length of joint bars. The importance of giving special spacing to joint ties less than for other ties is reviewed. The design of joint bars is discussed and comparisons are made of the properties of a number of forms. Study sections for symmetrical joint bars for the new 112-lb. R.E., 131-lb. R.E., and 152-lb. P.S. rails are given.

In the general discussion of the tests of track, the method of determining the value of the modulus of elasticity of rail support u for use in calculating rail stresses and depressions and pressures is described. The relations of rail sizes and properties, rail-support stiffness, and wheel spacing to rail stress and moment and depression and to tie load are discussed for groups of wheels as having influence on the durability and upkeep of track. The influence which the strength and stiffness of rail and the stiffness and uniformity of the substructure below the rail exerts upon the quality of the track is discussed. The advantages of stiff rail support on matters of permanence of surface and resulting maintenance are noted. The need for better control of tamping operations to overcome the variability in rail support and its accompanying defects is considered. Altogether, it is concluded that the advantages and the usefulness of track that is smooth under its load, both from tie to tie and through longer distances—high-grade track in all respects—have real values worthy of serious consideration.

2. **Acknowledgment.**—As has been the case in recent years, the expenditures in carrying on the work of the investigation have been taken principally from funds provided by the American Railway Association. The Committee expresses its appreciation of this support. Another fund which has continued to be helpful in meeting expenses is the contribution received from companies that manufacture steel rails, which was acknowledged more fully in the Fifth Progress Report.

The cooperation of railroads in furnishing facilities for the test work is always an important contribution. Three railroads gave excellent opportunities for the conduct of test work by providing locomotives and heavily loaded cars, track, train crews, and

other facilities throughout a considerable time. Acknowledgment for the opportunities and facilities in making the tests on the Pennsylvania Railroad is due T. J. Skillman, Chief Engineer, Robert Faries, Assistant Chief Engineer Maintenance, and F. M. Graham, Assistant Engineer Standards. Credit is due the Westinghouse Electric and Manufacturing Company, F. E. Wynne, Manager Railway Equipment Engineering Department, Charles Jablow, Railway Equipment Engineer, and Messrs. Shamberger and Langer for opportunities to use the testing equipment at Claymont, Delaware, and for the development of a magnetic strain gage suitable for testing rail-joints. Acknowledgment is made to the Chesapeake and Ohio Railway, C. W. Johns, Chief Engineer, for the test facilities accorded at Ashland, Kentucky, and to M. I. Dunn, Jr., Division Engineer, for local arrangements. Credit is likewise due the Missouri Pacific Railroad, the late E. A. Hadley, Chief Engineer, W. J. Burton, Assistant to Chief Engineer, and A. A. Miller, Engineer Maintenance of Way, for opportunity and facilities for making tests of track. Important assistance was also rendered by many operating officials.

The staff engaged in the field, laboratory and office work has continued to give valuable service. E. E. Cress, Assistant Engineer of Tests in charge of conduct of field and office work and the reduction of data and preparation of material, is entitled to special credit; as heretofore, his thorough familiarity with details, keen grasp of the problem, and helpfulness in the study and preparation of the data and report have made his services particularly valuable. Randon Ferguson also has continued to give important and valuable service in the field and laboratory work, the reduction of data, and the preparation of the report. Other members of the staff have given loyal and useful service in the various parts of the investigation.

The University of Illinois has continued to cooperate in the work by giving the use of laboratory, shop, and office facilities, and through the service of members of the staff of the Engineering Experiment Station from time to time.

3. **Previous Progress Reports.**—The principal results of the earlier investigations and their interpretation and findings have been reported in five Progress Reports, which are to be found in the Proceedings of the American Railway Engineering Association as follows: First Progress Report, Vol. 19 (1918) page 873; Second Progress Report, Vol. 21 (1920) page 645; Third Progress Report, Vol. 24 (1923) page 295; Fourth Progress Report, Vol. 26 (1925) page 1081; and Fifth Progress Report, Vol. 31 (1930) page 65. The First, Second, Third and Fourth Progress Reports were also printed in the Transactions of the American Society of Civil Engineers in Vol. 82 (1918), 83 (1920), 86 (1923) and 88 (1925), respectively. Discussion of the investigation by the chairman under the titles "Some Features of Rail Joints" and "The Desirability of Reducing to a Minimum the Present Variability Factors in Track" are to be found in Proceedings of the American Railway Engineering Association, Vol. 33 (1932) pages 746 and 750.

A summarized statement of the scope of the work and the topics and tests included in each of the first four progress reports is given on page 71 of the Fifth Progress Report. This outline of content covering four pages is sufficiently detailed to enable a reader to learn what parts of the investigation are treated in each report and to find the nature and purpose of the tests. Having found in this way a general topic or topics of interest and the number of the volume in which the report is printed, the location of the material can be learned by looking through the Contents at the beginning of each progress report.

The Fifth Progress Report contains chapters on General Structural Action of the Rail-Joint, The Mechanics of the Rail-Joint, The Laboratory Tests, The Field Tests, and General Discussion. The last-named chapter includes such topics as the function of the rail-joint, bolt tension, lateral bending, the rail-joint in track, the design of joint bars, miscellaneous features of rail-joints, uniformity and variability in track, and finally a review which summarizes briefly the topics and findings of the report.

II. LABORATORY TESTS OF RAIL-JOINTS

4. **The Function and Action of the Rail-Joint.**—In the Fifth Progress Report considerable space is devoted to the functions and action of the rail-joint, both analytically and experimentally. An effort was made to show its physical method of action when load is applied to the rail and rail-joint to learn the mechanics of its structural action; to find where forces act and react between head of rail and upper fishing surface of joint bar and between the lower fishing surface of the joint bar and the base of rail along the length of the rail-joint; to study the elements entering into the flexibility and stiffness and deflection of the rail-joint as a whole and the consequent variations in the pressures or loads on the ties; to learn the effect of high and low bolt tension; to observe the stresses and moments developed in the joint bars and to find wherein the moments developed in track differ from those in the full rail under varieties of conditions; to study the effect of form of section and of fit between rail and joint bars, as well as of lack of fit (play), on distribution of stresses, deflection of the joint, and flexibility of the track; and, among other things, to outline principles and methods that may be useful in designing rail-joints and in giving better understanding of the way in which a rail-joint performs its functions in the track.

Any attempt to summarize the findings of the tests and discussions of the Fifth Progress Report relating to the rail-joint would involve considerable space. The reader who wishes to learn something of the work done is referred to the Review at the end of the Fifth Progress Report and to the articles on the analysis and tests and discussions named in the Table of Contents of the Report. It may be well, however, to refer here to some of the elements in the action of the rail-joint brought out in the Fifth Progress Report. The rail-joint acts principally as a beam or girder. On the application of load to the rail at one or more points producing positive moment in the joint (downward bending), vertical pressures are applied by the head of the rail on the top of the fishing surface of the joint bars near the ends of the two rails, as may be represented at Q in (a) and (b) in Fig. 1, and at the same time reaction forces act between the base of rail and the lower fishing surface of the joint bars at points farther away from the rail ends, as at R in (a) or at R' and R'' in (b). With the more usual forms of rail-joints the position and distribution of these load forces on the top of the bar and of the reaction forces on the bottom are dependent upon conditions such as fit between bars and rail and tightness of bolts. Generally the resultant of the load pressure of rail on top of bar (Q) may be considered to be near the rail end as shown in (a) and (b). The resultant of the pressure reactions on the bottom of the bar may sometimes be represented by a single force for each half of the length of bar, as R in (a), or more commonly, especially for tight bolts and well-fitting joints of such forms, the reaction forces may be approximated by two resultants in each half of the length of the bar as shown by R' and R'' in (b). For negative bending moments (upward bending) the load pressures will be applied on the bottom of the bar and the reaction forces on the top as shown in (c).

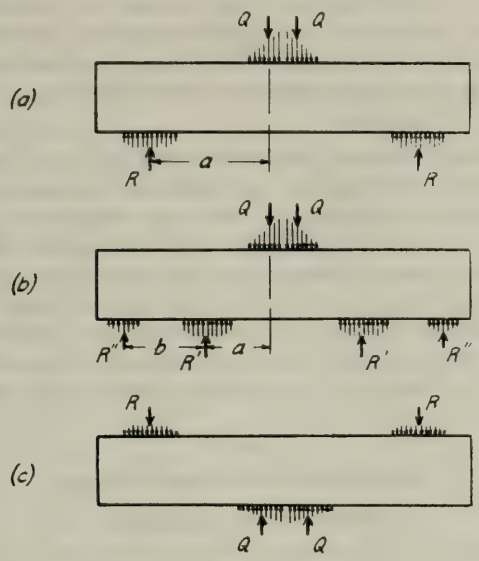


Fig. 1.—Diagram Showing Vertical Load Pressures and Reactions on Joint Bars. (a) Single Reaction Bearings for Positive Moment. (b) Double Reaction Bearings for Positive Moment. (c) Single Reaction Bearings for Negative Moment.

It was shown in the investigation that the shape of section affects the action of the rail-joint. In a shape that is unsymmetrical with respect to the horizontal axis, such as the usual form of angle bar, the mechanics of the beam action differs from that which has been assumed ordinarily in calculations made on rail-joints—the neutral axis under a vertical loading deflects away from the horizontal line, the stresses are not proportional to the vertical distances from the fibers to the horizontal gravity axis, but the stress varies proportionally to the perpendicular distance from the inclined neutral axis developed by the unsymmetrical section and the deflection of the bars is perpendicular to this neutral axis. The amount of these variations depend upon the shape of the bar, the fit between rail and bar, and the restraint produced by fit and bolt tension. The advantages of symmetrical sections and the methods of determining effects of dissymmetry were discussed in the Report including formulas and methods for determining the properties and characteristics of any section.

Fit of the rail-joint and play between rail and bar at ends and middle, even what may be thought to be minute play, were considered in their effect on deflection and depression at the rail-joint relative to that in full rail elsewhere and in their relation to the moments developed in the rail and rail-joint as well as to track maintenance. Attention was given to the usefulness of spacing three or four ties at the rail-joint closer than the tie spacing elsewhere, in reducing the depression at the rail-joint and the moment developed in the joint bars as compared with what they would be for uniform spacing, and thus in improving track conditions and reducing cost of maintenance. Many other matters were discussed and reported in the investigation.

In the chapter on "The Mechanics of the Rail-Joint" of the Fifth Progress Report the flexural action of the joint bar was considered analytically at some length under the assumption that the measured strains in a given section of the joint bar are representative of flexural stresses and that strains caused by bearing pressures or other distortions of the section need not be considered.

In the calculation of moments developed in joint bars from the observed stresses given in this report for both laboratory and field tests, the analytical methods of the Fifth Progress Report are employed as a basis with modifications made to take into account the effect of bearing strains or other local bending when found necessary. In general, the calculated bending moments (or more properly, resisting moments) were computed by equation (67)*, page 111 of the Fifth Progress Report, using the observed stresses and the coordinates for the two gage lines considered. The two gage lines should preferably be taken at two points as far apart in the section as practicable, one near the top and one near the bottom, and if possible the position of the gage lines should be

TABLE 1

Properties of the Rail Sections

Units are inches and pounds.

Rail Section	Moment of Inertia			Section Modulus		
	Area	Horizontal Axis	Vertical Axis	Horizontal Axis		Vertical Axis
				Base	Head	Base
90-lb. A.R.A.—A.	8.80	38.7	7.5	15.2	12.6	2.9
110-lb. R.E.	10.82	57.0	10.6	20.1	16.7	3.9
112-lb. R.E.	11.05	66.1	11.0	22.0	18.3	4.0
127-lb. N.Y.C.	12.48	83.7	14.8	27.0	21.5	4.7
130-lb. R.E.	12.71	77.4	14.5	25.6	20.8	4.8
130-lb. P.S.	12.70	72.8	13.3	23.5	20.6	4.8
131-lb. R.E.	12.86	88.6	14.5	27.4	22.8	4.8
152-lb. P.S.	14.88	128.6	20.4	36.7	28.6	6.1

chosen where the measured strain is representative of the flexural stress and not influenced by bearing strains or local bending stresses that are found at certain places at certain sections along the joint bar. When a gage line must be placed where it does not give the true flexural stress, as at a point on the upper portion of the inner joint bar where the instrument will be clear of the wheel flange, special approximate methods will have to be used in the calculations to take account of the variation of the strain from that of the flexural stress. These methods of calculation will be described later.

* Equation (67) is

$$M_x = \left(\frac{I_x x_2 - J_{xy} y_2}{y_1 x_2 - x_1 y_2}\right) s_1 + \left(\frac{J_{xy} y_1 - I_x x_1}{y_1 x_2 - x_1 y_2}\right) s_2 \quad \ldots\ldots\ldots\ldots \quad (67)$$

where M_x is the vertical moment (resisting moment in the vertical planes), x_1 and y_1 are the abscissa and the ordinate of the point in the section for gage line 1 taken with reference to the horizontal and vertical geometrical axes of the section, and x_2 and y_2 are similarly the coordinates for gage line 2, and s_1 and s_2 are the corresponding measured stresses, respectively, at the two gage lines.

TABLE 2

Description and Properties of Joint Bars

Units are inches and pounds. All values are for a single bar. The subscript denotes the axis to which the properties correspond.

Name	Rail Section	Type of Section	Length of Bar	Number of Bolts	I_x	I_y	J_{xy}	Section Modulus	Area
I. C., No. 3	90-lb. A.R.A—A.	Angle bar	24	4	8.05	2.50	3.00	3.54	4.46
N.Y.C., No. 5	105-lb. N.Y.C.	Angle bar	36	6	8.90	2.05	2.75	3.48	4.32
N.Y.C., No. 1 and 2	127-lb. N.Y.C.	Angle bar	38	6	17.25	4.45	5.60	5.71	6.01
Penn. L-3, No. 1, 2, 5 and 11	130-lb. P.S.	Angle bar	38½	6	16.55	5.15	6.15	6.54	6.34
Penn. Sym., No. 2	130-lb. P.S.	Near-symmetrical	38½	6	10.25	1.65	−.35	4.60	6.37
Santa Fe, No. 1	130-lb. R.E.	Near-symmetrical	26	4	13.35	2.00	.80	5.57	6.34
N. & W. H.B., No. 1	130-lb. P.S.	Head-bearing Continuous	24	4	26.90	5.80	6.15	8.73	7.86
N. & W. H.F., No. 1	130-lb. P.S.	Head-free Continuous	24	4	27.45	6.00	6.25	9.75	7.99
Study section I	112-lb. R.E.	Near-symmetrical	----	--	12.65	1.55	.95	5.24	5.85
B. & O.	130-lb. R.E.	Angle bar	25	4	20.65	7.50	8.10	7.88	7.39
Penn. F-4	131-lb. R.E.	Near-symmetrical	38½	6	12.20	.80	.75	4.81	5.20
Study section G	131-lb. R.E.	Near-symmetrical	----	--	18.55	2.30	1.30	7.10	7.04
Penn. F-1	152-lb. P.S.	Near-symmetrical	38½	6	18.45	.95	1.30	6.11	6.26
Study section H	152-lb. P.S.	Near-symmetrical	----	--	27.60	2.35	1.35	9.14	7.58

5. **Properties of Rails and Joint Bars.**—For convenience of reference the geometrical and analytical properties of the sections of rails and of most of the joint bars used in the tests herein reported are given. Table 1 contains the areas, moments of inertia with respect to horizontal and vertical axes, and section moduli of various rail sections with reference to the remotest fiber of the base and the head of rail. Fig. 2 gives sections and dimensions of rails used in the tests. In Fig. 3 are shown sections of joint bars and the position and designation of the gage lines used. In Table 2 are given various properties of the joint bars, including moments of inertia with respect to hori-

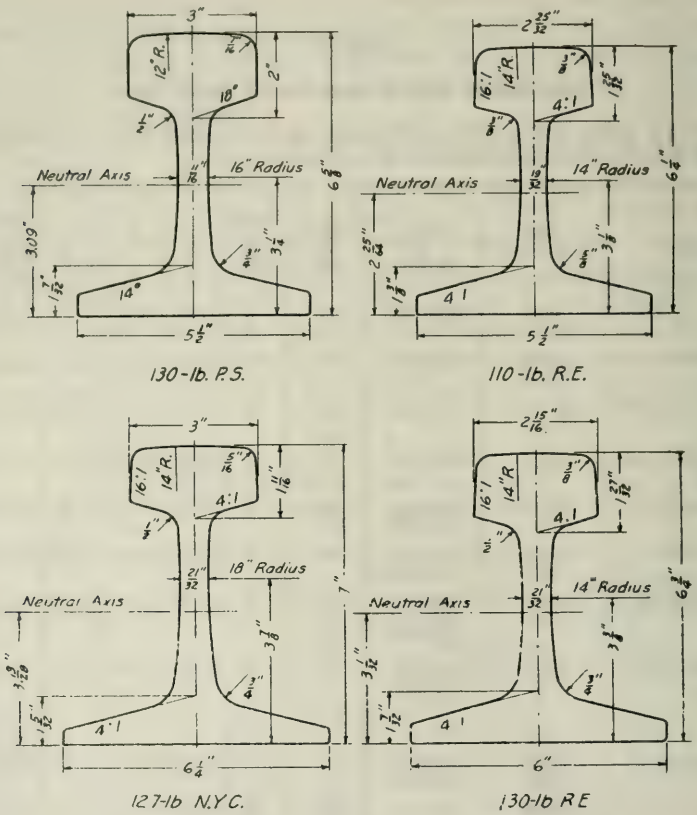


Fig. 2.—Sections of Rails Used in the Tests.

zontal and vertical axes (I_x and I_y), product of inertia with respect to horizontal and vertical axes (J_{xy}) and section modulus with respect to the horizontal axis and the uppermost fiber (the lowermost fiber in the Santa Fe symmetrical bar and study section H)—including several study sections of joint bars which are referred to in Chapter VII.

6. **The Laboratory Tests of Rail-Joints.**—The laboratory tests reported in this Sixth Progress Report relate mainly to the rail-joint. General studies were made of the action of several forms of rail-joint not previously reported on or having features somewhat different from those used in the earlier laboratory tests. Tests with the load and span placed successively farther and farther along the rail and rail-joint to simulate to some degree the condition in track found with a wheel load advancing along the rail and over a rail-joint have given new information on the progressive changes in stresses, moments, and vertical and lateral movements in the rail-joint. The lateral movement of the joint bars in tightening and loosening bolts and the spring (elastic and otherwise) put into the bars by bolt tension have been given some attention. Tests to determine

the relation between stresses at different points over the section of the bar for particular sets of rail-joints were made for use in interpreting the stresses and determining the moments developed in rail-joint and joint bars in the track tested with loaded cars and locomotives. A few miscellaneous tests are also reported.

Following is a description of the procedure in the laboratory tests of rail-joints: Two set-ups were used in the laboratory tests herein reported. For the earlier tests, two equal loads were applied to the rail at points 3 to 6 in. outside of the ends of the joint bars and the supports were placed 16 in. further out from the loads; this set-up developed a uniform bending moment at all sections between the two loads and thus eliminated some possible complications in the action of the rail-joint. For the later tests a single load at the middle of a 48-in. span was applied. This procedure gave a uniformly decreasing moment from load point to ends of span; in some ways it approached more

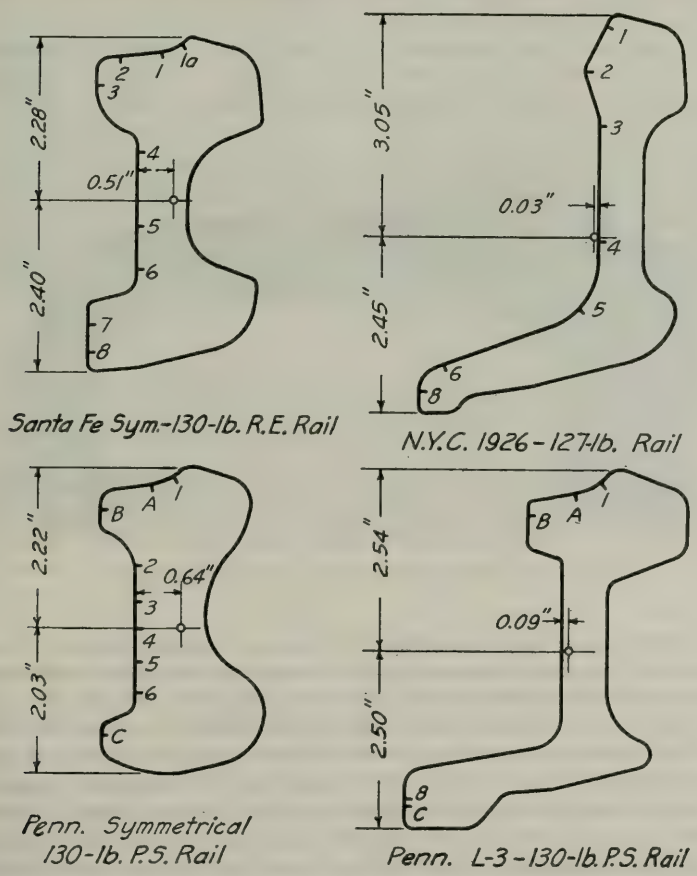


Fig. 3.—Sections of Joint Bars and the Position and Designation of the Gage Lines Used.

closely the distribution of moments at the sections away from the wheel load found in track, though of course the effect of inequalities in tie reactions from point to point along the track was not reproduced.

The measurement of strains in the rail and joint was made by means of 2-in. and 4-in. Berry strain gages. A description of the strain gage is given in the First Progress Report of the Committee on Stresses in Railroad Track (Proceedings of the American Railway Engineering Association, Vol. 19, 1918, page 898). The methods used in taking strain gage readings are also described in the First Progress Report. The 2-in. strain gage was used more especially to obtain the stress throughout the middle portion of the length of the bar where the rate of change of stress was very great. Duplicate readings were always taken. If the two readings did not agree closely further observations were made. It is believed that with the skill used by the observer the errors of observation were less than 600 lb. per sq. in. for the 2-in. gage lengths and 300 lb. per sq. in. for the 4-in. gage lengths. It should be borne in mind that the strains measured are average strains over the gage lengths used. Standard reference bars with the same length of gage line were used throughout the tests and suitable corrections were applied to the readings to compensate for temperature changes and to warn against instrumental mishaps. For special purposes measurements were also made with a ½-in. Huggenberger gage attached to the joint bar or rail and measuring ½-in. gage length.

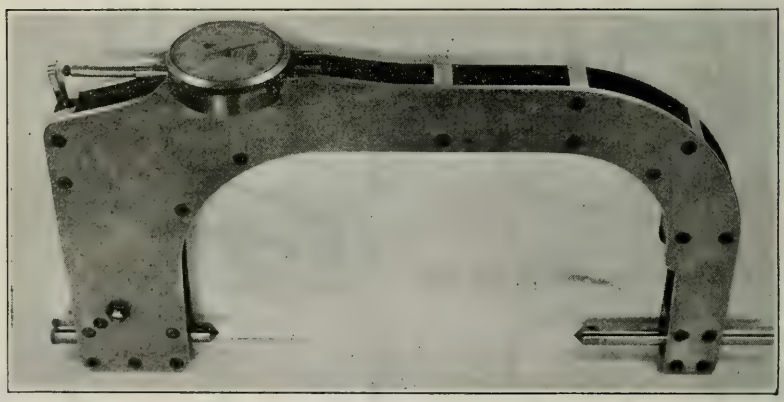


Fig. 4.—Improved Form of Caliper Extensometer.

Two methods were used in measuring the tension in the joint bolts—(a) the caliper extensometer and (b) the extensometer bolts. The earlier form of the caliper extensometer is described in the Fifth Progress Report on page 114. The improved form is shown in Fig. 4. It has a greater range of movement to provide for variations in lengths of bolts. The frame and points were made of Invar steel. The design and material used in the instrument were found to be compensating for temperature changes. The moving point of contact in the new instrument is at the end of a plunger which slides horizontally and the other end of the plunger bears against the lower part of the multiplying lever; thus the position of the point on the end of the bolt is maintained accurately throughout the range of travel. A hole similar to that used for strain gage measurement is drilled in each end of the bolts to receive the conical bearing points of

the instrument. Satisfactory results were obtained without grinding the ends of the bolts. In general, the measurements of tension taken with the new instrument are believed to be accurate within 300 lb., unless the measurement is complicated by temperature changes in the bolt. The bolt extensometers are described on page 114 of the Fifth Progress Report. They are 1-in. heat-treated alloy steel. Fig. 5 gives a view of the extensometer bolts applied to a rail-joint.

Deflection of the rail-joint in the span length was measured with the aid of a dial gage. This gage was mounted on a wooden bar which was supported by conically pointed rods that were fixed rigidly to the bar. When taking readings the points were held in punch marks on the head of the rail. This measurement was thus unaffected by the deflections of the supports upon which the rail-joint rested. The joint bar deflections were measured in the same manner with a bar of correspondingly shorter length. With proper precautions the deflections were obtained within .001 in.

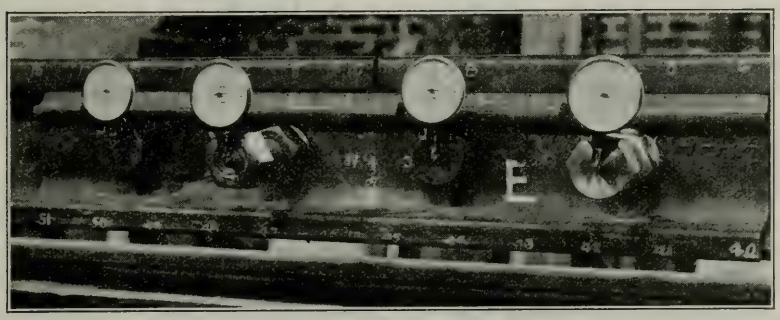


Fig. 5.—Extensometer Bolts Applied to a Rail-Joint.

7. **General Studies of the Action of Rail-Joints.**—The results of the laboratory tests relating to the general studies of the action of rail-joints will be presented for the several forms of joint bars under separate headings.

7a. **N.Y.C. Rail-Joint for 127-lb. N.Y.C. Rail.**—Both the angle bars and the two pieces of rail in this New York Central rail-joint for 127-lb. rail were new and unused. The section of the bar and the location of the gage lines are shown in Fig. 3 and its properties are given in Table 2. The results given are for a single load of 33,300 lb. at the middle of a span of 48 in. and a maximum moment of 400,000 in.-lb. In Fig. 6 are given the compressive stresses along the top of the bar (point 1) and the tensile stresses along the edge of the lower flange (point 8), one test with an average tension of 20,000 lb. in each of the six bolts and another test with 2,000 lb. bolt tension. It will be noted that at mid-section the stress in the top gage line is more than double that at the gage line near the bottom of the bar and that the tensile stresses at the bottom remain nearly constant throughout the middle 8 in. of length of the bar, while the compressive stress at the top decreases rapidly from the mid-section each way. These differences may be explained by the changes in restraint of the bar from point to point along the length and the consequent modification of the inclination of the neutral axis. For the 20,000 lb. bolt tension the angle of inclination of the neutral axis, as determined by calculation by equation (55) of the Fifth Progress Report and the use of stresses at gage line 1 and 8, changes from +15° at mid-section to —15° at 4 in. on either side. For the 2,000 lb.

bolt tension the angle of inclination is found to change from +20° at mid-section to —3° at 4 in. either side. With 20,000 lb. bolt tension the peak in the compressive stress at mid-section is marked; with 2,000 lb. bolt tension the compressive stress falls off less rapidly away from the mid-section. The relative values of the two reaction forces which would give approximately the same moments as are developed along the bars are quite different in the two cases; for 20,000 lb. bolt tension the values are approximately 27,000 and 16,000 lb. for R' and R'' (see Fig. 1), and for 2,000 lb. bolt tension the interior reactions are smaller than the end reactions, say 14,000 and 17,000 lb., respectively.

The lateral movement of the top and bottom of the angle bar on the application of a load of 25,000 lb. was measured at eight points along the length of each bar with results as plotted in Fig. 7. With a bolt tension of 2,000 lb., at mid-section the movement was .001 in. outward from the rail at the top of the bar and .005 in. inward at the bottom. At the ends of the bars the top movement was .0015 in. outward and the bottom movement .003 in. outward. At intermediate points, the top movement showed changing curvature laterally along the length of the bar, outwardly at the middle and inwardly at the quarter points, while the bottom movement curved inwardly with some regularity from mid-section to end of bar. The results indicate the twisting action of the angle bar from point to point along its length. The marked inward movement of the bottom of the bar at mid-section is attributed to the lack of symmetry of the section of the bar and the consequent inclination of the neutral axis at this section, so that the deflection is downward and inward. For the 20,000 lb. bolt tension the added restraint due to the higher bolt tension has resulted in a reduction in the inward movement of the bottom of the bar at mid-section to about .001 in., while the movement of the top of the bar was not greatly different from that with the lower bolt tension. Elsewhere the movement at both top and bottom was almost entirely eliminated.

Measurements were made at nine gage lines on the mid-section. The distribution of the stresses over the section from top to bottom was found to be quite similar to the distribution observed in the tests of N.Y.C. rail-joints made for the Fifth Progress Report.

It should be noted that this rail-joint has an excellent fit. This was shown not only by inspection and measurements of the rail-joint—the excellence of the fit is borne out by the small magnitude of the vertical movement of the bars with respect to the rail upon application of load and by the form of the curve of stresses and loads along the length of the joint bars.

7b. **Penn. Rail-Joint for 130-lb. P.S. Rail.**—Penn. L-3 rail-joint No. 1 was a new (unused) joint with 38½-in. angle bars for 130-lb. P.S. rail. The section of the bar and the location of the gage lines are shown in Fig. 3 and its properties are given in Table 2. In Fig. 8 are given the stresses along the top of the bar and along the edge of the lower flange, one test with a bolt tension of 20,000 lb. and one with 2,000 lb. In this rail-joint, as in the N.Y.C. rail-joint, the stress in the top gage line at mid-section is more than double that at the bottom of the bar and the tensile stress at the bottom remains nearly constant through the middle 8 in. of length of the bar, while the compressive stress at the top decreases very rapidly from the mid-section each way. These differences are, of course, due to dissymmetry in the section of the angle bar and to the restraints applied to the bar. For the 20,000-lb. bolt tension the angle of inclination changes from +25° at mid-section to —45° at 4 in. on either side. For the 2,000-lb. bolt tension the angle of inclination changes from +25° at mid-section to 0 at 4 in. each side. With 20,000 lb. bolt tension the peakedness in the compressive stress at mid-

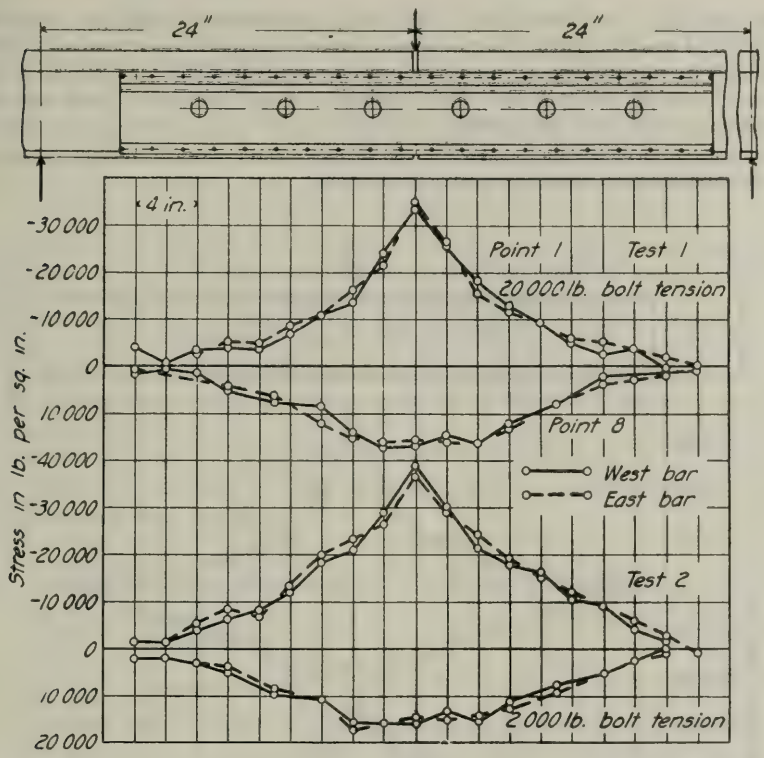


Fig. 6.—Observed Stresses in Angle Bars at Sections along Their Length—N.Y.C. Rail-Joint for 127-lb. N.Y.C. Rail—Bolt Tensions 20,000 and 2,000 lb. —Load 33,300 lb.

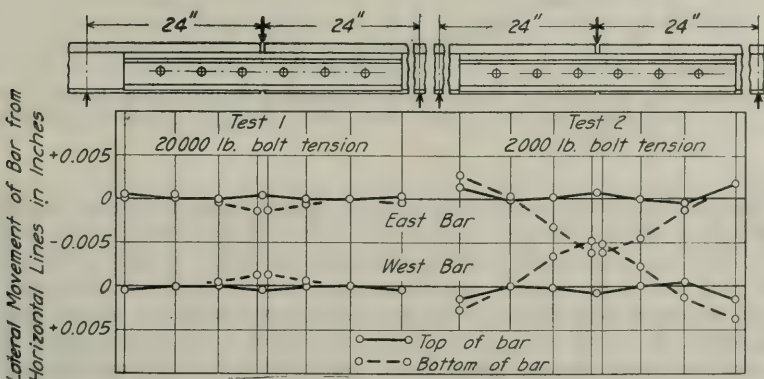


Fig. 7.—Lateral Movement at Top and Bottom of Angle Bar on Application of Load of 25,000 lb.—N.Y.C. Rail-Joint for 127-lb. N.Y.C. Rail—Bolt Tensions 20,000 and 2,000 lb.

length is marked. Calculated values of the stresses and moments at different points along the length of the bar which will approximate the measured values may be obtained for the 20,000-lb. bolt tension by considering reactions of 59,000 lb. to be located at 4 in. each way from the rail ends and other reactions of 11,000 lb. at 18 in. each way from the rail ends, while with the 2,000-lb. bolt tension values of reactions at the same two positions given of 30,000 and 18,000 lb. respectively, would approximate the distribution of stress and moment along the length of the bars.

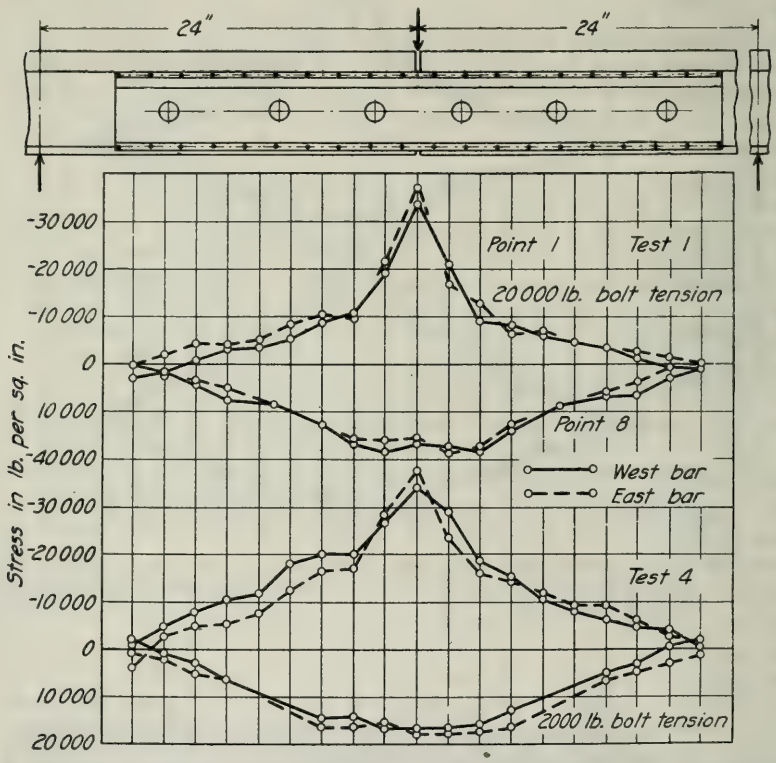


Fig. 8.—Observed Stresses in Angle Bars at Sections along Their Length—Penn. Rail-Joint for 130-lb. P.S. Rail—Bolt Tensions 20,000 and 2,000 lb.—Load 33,300 lb.

The lateral movement of the angle bars with respect to the rail on the application of the load of 33,300 lb. at the middle of the 48-in. span was similar to that given in Fig. 7. With a bolt tension of 20,000 lb., the lateral movement of the top of the angle bar at 6, 12, and 18 in. from the mid-section was extremely slight, say about .0002 in., generally outwardly from the rail, while the bottom points move very slightly one way or the other. At the rail ends, the top of the bar showed a very small outward movement and the bottom moved inward about .002 in. The vertical movement between rail and bar was also very small at the 6, 12, and 18 in. points. At the rail ends the rail and bar moved vertically toward each other about .002 in.; at least part of this movement was a detrusion of the two bearing surfaces, the measurements being made

from a point on the side of the head of the rail about an inch below its top to a point on the web of the bar. With the 2,000-lb. bolt tension, the few lateral measurements made indicated that the bottom of the bar moved inward .003 in. at the mid-section and outward .002 in. at the ends of the bar.

Measurements of stresses were made at 15 gage lines on the mid-section. There was a greater deviation from straight line distribution of stress than with the N.Y.C. rail-joint. It seems probable that this variation was due to differences in the location and amount and concentration of the top bearing pressures in the two joints.

It should be noted that this rail-joint also has an excellent fit. The very small vertical and lateral movements and the form of the stress distribution curve along the length of the joint bars all indicate closeness of fit and restraint of bars.

In Fig. 9 is shown the inclination of the neutral axis at various points along the length of the bar as calculated from stresses measured at the top and bottom of the bar and given in Fig. 8 for tests with 20,000 and 2,000-lb. bolt tension. The change from positive to negative inclination is due to changes in the lateral and vertical restraints at different places along the length of the bar. It is evident that the high bolt tension gives much higher restraints with stronger twisting forces near the middle, and that with low bolt tension there is greater opportunity for lateral movement and lateral flexure of the bar.

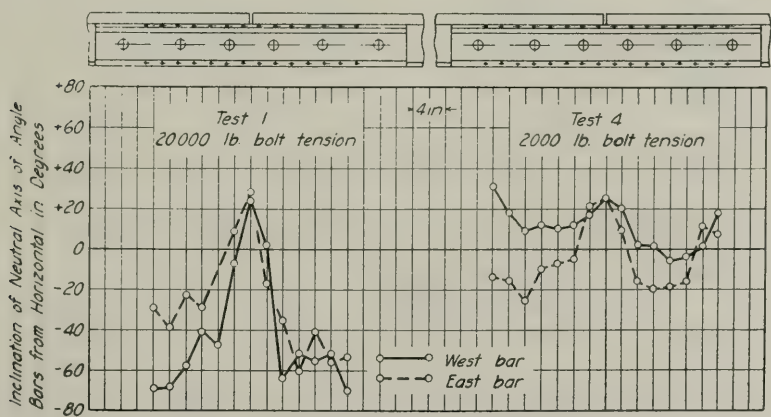


Fig. 9.—Inclination of Neutral Axis in Angle Bars at Sections along Their Length —Penn. Rail-Joint for 130-lb. P.S. Rail—Bolt Tensions 20,000 and 2,000 lb.

The changes in bolt tension upon application and removal of load were similar to those for angle bar rail-joints reported in the Fifth Progress Report. On repeated application of load, with 20,000-lb. bolt tension, the tension in the inner bolts dropped off much more rapidly than did that in the intermediate bolts, while at the same time the tension in the end bolts dropped slightly at the first applications and afterward slowly or not at all. For 2,000-lb. bolt tension the tension in the end bolts increased 500 lb. to 1,000 lb. upon applications of load and dropped back upon their removal, the change in tension in the unloaded condition remaining small. The inner and intermediate bolts were little affected by loading and unloading.

The angle bars in Penn. rail-joints 5 and 11 had been taken from the track tested at Claymont, Delaware (tests designated as (f) and (j) in Chapter III "Tests of Rail-

Joints on the Pennsylvania Railroad"); they were the same form of joint bars as Penn. rail-joint No. 1 described above. No. 11 had been in track under heavy passenger traffic for two years, and No. 5 for a few months. In Fig. 10 are given the stresses and moments in Penn. rail-joint No. 11 along a length of 6 in. each way from the mid-section for a load of 33,300 lb. The moments were calculated by equation (67) and the method outlined in Article 4 "The Function and Action of the Rail-Joint." The stresses at mid-section correspond closely with those in Fig. 8. The distribution of stresses along the bar is somewhat different, a condition probably due to wear of the bar. Penn. rail-joint No. 5 gave similar results.

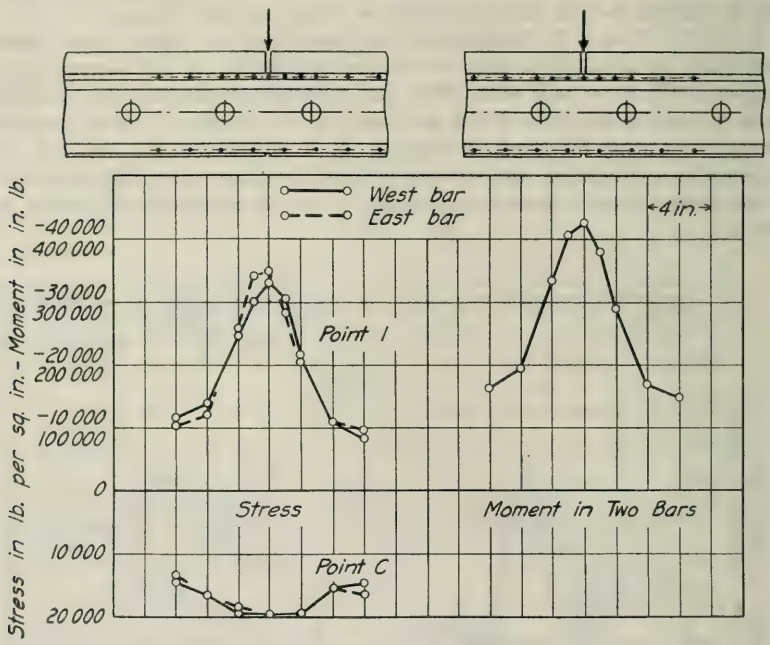


Fig. 10.—Observed Stresses and Moments in 38½-in. Angle Bars at Nine Sections along Their Length—Penn. Rail-Joint No. 11 for 130-lb. P.S. Rail—Bolt Tension 20,000 lb.—Load 33,300 lb.

Penn. rail-joint No. 1 (lat. def.), with laterally deformed bars, (also taken from the track at Claymont, Delaware, test designation (g)) had been in service a short time. The regular L-3 38½-in. angle bars had been deformed laterally by pressing the head and base laterally outward in an attempt to relieve the bearings between rail and bar on the fishing surfaces at the top and bottom for 3 or 4 in. along the length of the joint at the quarter points. This modification would tend to improve the fit or assure a good bearing at the rail ends and cause the reaction bearings of the loaded joint to be moved along the bottom of the bars to places farther from the middle than is ordinarily found in well fitting rail-joints. The actual condition found in the laboratory test of this joint was that the lateral deformation obtained at the bottom bearing surface was insufficient to assure clearance over the deformed length, and this part of the bar may

have had partial bearing on the base of the rail in this area. Fig. 11 gives the distribution of the stresses and moments along the length of these laterally deformed bars. An effect of laterally deforming these bars seems to be a flattening of the peak of the compressive stress at the middle of the length of the bar and a similar change in the moment diagram. It is evident that the resultants of the top bearing forces are farther from the

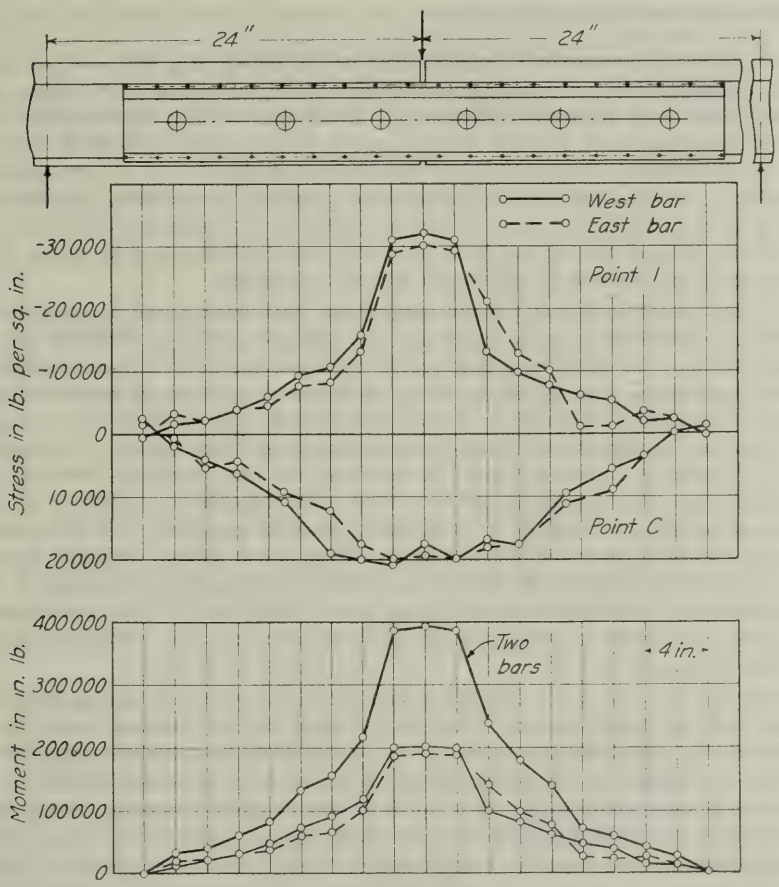


Fig. 11.—Observed Stresses and Moments in Angle Bars at Sections along Their Length—Penn. Rail-Joint No. 1 (Laterally Deformed) for 130-lb. P.S. Rail—Bolt Tension 20,000 lb.—Load 33,300 lb.

rail ends than is the case with the ordinary bar. It is evident from the shape of the moment diagram in Fig. 11 (flat top and freedom from sharp peak, with a sharply descending line at the ends of the flat top) that the interior reactions (R' of Fig. 1) may be considered to be located at about 2 in. each way from mid-length, which is greater than the distance usually found in the tests, and that the flatness of the top indicates that the rail ends do not "dig" into the top of the bar as is generally possible. Just what change the deforming process has given to the bar at its middle to produce

the last mentioned effect is not definitely known. The form of the flexure of the bar at the middle of its length effected by tightening both the inner and the intermediate bolts is probably the source of this advantageous condition. It is seen that the tensile stresses along the bottom remain nearly constant through the middle 12 in. of length; this again is due to a change in position in the top bearing forces and probably also to the conditions of restraint. Conclusions on the effects to be obtained by deforming joint bars laterally cannot well be drawn from the test of one rail-joint of the type.

7c. **Penn. Symmetrical Type Rail-Joint for 130-lb. P.S. Rail.**—A pair of the Penn. Symmetrical type of joint bars for 130-lb. P.S. rail, taken from joint 2 in the track of the Pennsylvania Railroad at Claymont, Delaware was tested in the laboratory. The section (see Fig. 3 and Table 2) has an area of 6.37 sq. in., a moment of inertia of 10.25 and a section modulus of 4.60, and a product of inertia of —.35, as compared with 6.34, 16.55, 6.54, and 6.15 for the corresponding properties of the Penn. L-3 angle bar. It will be noted that the moment of inertia and the section modulus are small as compared with those of the L-3 bar for a horizontal neutral axis and that the design of the section does not give high effectiveness in stiffness and strength.

In Fig. 12 the stresses at top and bottom gage lines under a load of 33,300 lb. are plotted for the middle 12 in. of length, one test with bolt tension of 20,000 lb. and one with 4,000 lb. The upper gage lines are 2.1 in. above the horizontal geometrical axis of the bar and the lower 1.5 in. below it. In the same figure the moments calculated from the measured stress are given for both the 20,000-lb. and the 4,000-lb. bolt tension. It is seen that the results with the two bolt tensions are strikingly similar. The distribution of stresses and moments along the length of the bar are almost identical. The reactions which give approximations to both moment diagrams are 40,000 lb. at 4 in. from mid-section and 15,000 lb. at 16 in. away. Thus the conditions of fit and restraint of the bars are not particularly affected by the change in bolt tension. The ratio between the stresses at the top and the bottom gage lines at mid-section, as influenced by the concentration of bearing pressures at the top fishing surface and by other actions affecting twist and position of neutral axis, are nearly the same, and this is true also at other sections.

The stress at the top of the bar at mid-section was 43,000 lb. per sq. in., which agrees with the calculated stress. For the L-3 angle bars the measured stress for the corresponding point averaged 36,000 lb. per sq. in. while the calculated value on the basis of a horizontal neutral axis was 30,000 lb. per sq. in. The section modulus of this symmetrical type of bar is only 71 per cent of that of the L-3 angle bar and is much smaller than that of study section A of the Fifth Progress Report. The design of this Penn. symmetrical type joint bar is stocky and has a very thick web as compared with the head and base and as compared with other bars. Necessarily it has a restriction in height because of the relatively small fishing height in the 130-lb. P.S. rail section. Relatively few bars of this section have been used in track.

7d. **Santa Fe Symmetrical Type Rail-Joint for 130-lb. R.E. Rail**—The Santa Fe symmetrical type section for 130-lb. R.E. rail (see Fig. 3 and Table 2) resembles closely one of the near-symmetrical study sections (F) designed for analytical discussion in the Fifth Progress Report. The rail-joints tested were received from the Atchison, Topeka and Santa Fe Railway and had bars 26 in. in length and four bolts, but otherwise the joint bars were the same as those in the track tested on the Chesapeake and Ohio Railway, which were 39 in. long and had six bolts.

Fig. 13 gives the stresses in rail and joint bars for bolt tensions of 20,000 and 2,000 lb. in a test with a load of 50,000 lb. applied equally at two points 36 in. apart on a span of 68 in., thus developing a constant moment of 400,000 in.-lb. throughout the length of 36 in. In the same figure are given the moments in rail and two bars and

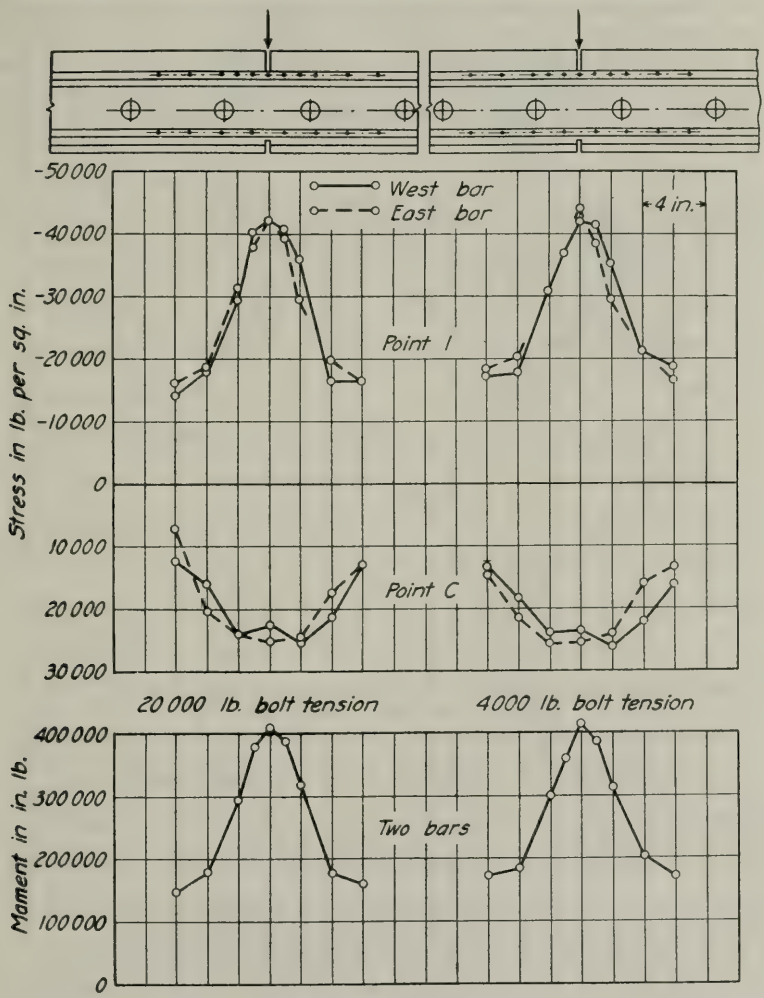


Fig. 12.—Observed Stresses and Moments in 38½-in. Joint Bars at Nine Sections along Their Length—Penn. Rail-Joint No. 5 for 130-lb. P.S. Rail—Symmetrical Type Joint Bar—Bolt Tensions 20,000 and 4,000 lb.—Load 33,300 lb.

their sums along the length of the rail-joint for tests with the two bolt tensions. The corresponding values of the stresses and the moments are nearly the same for the two bolt tensions, regardless of the differences in restraint given by the bolt tension. It is

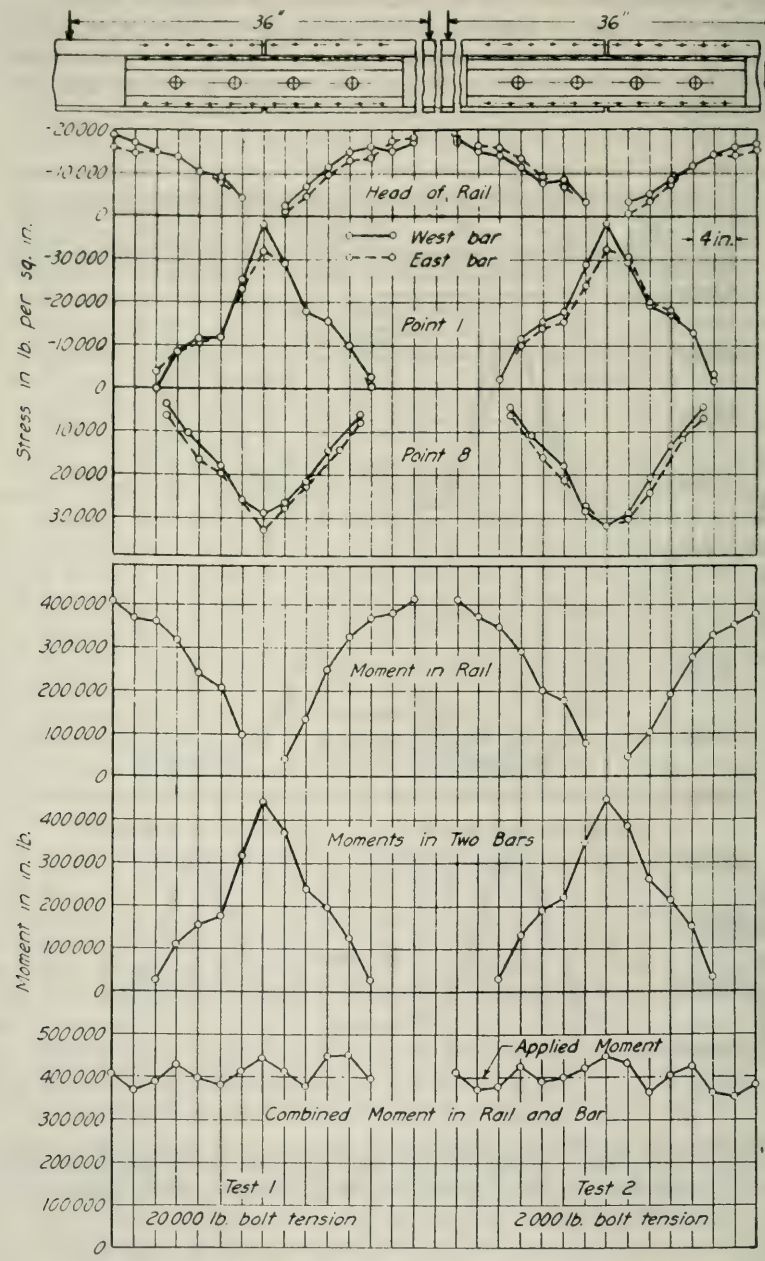


Fig. 13.—Observed Stresses and Moments in Rail and Joint Bars at Two Gage Lines for Eleven Sections along Their Length—Santa Fe Symmetrical Type Joint Bars for 130-lb. R.E. Rail—Bolt Tensions 20,000 and 2,000 lb.—Load 50,000 lb.

seen also that the stresses at top and bottom gage lines have nearly the same magnitudes at corresponding points along the length of the bars. This lack of variation is attributable to the symmetry of the section and is in marked contrast to the variability found in rail-joints of the angle bar type. Besides, the stresses, except at areas affected by strong concentration of bearing loads, correspond closely to the stresses found by calculation from the applied moment using the ordinary formulas of mechanics. This form of section thus acts efficiently throughout in the manner of beam action generally assumed in treatises on resistance of materials except as certain points in the section may be affected by the bearing pressures applied by the rail. Other tests, with a single load applied at the middle of the span at the rail ends, gave corresponding values and distributions of stress in the joint bars.

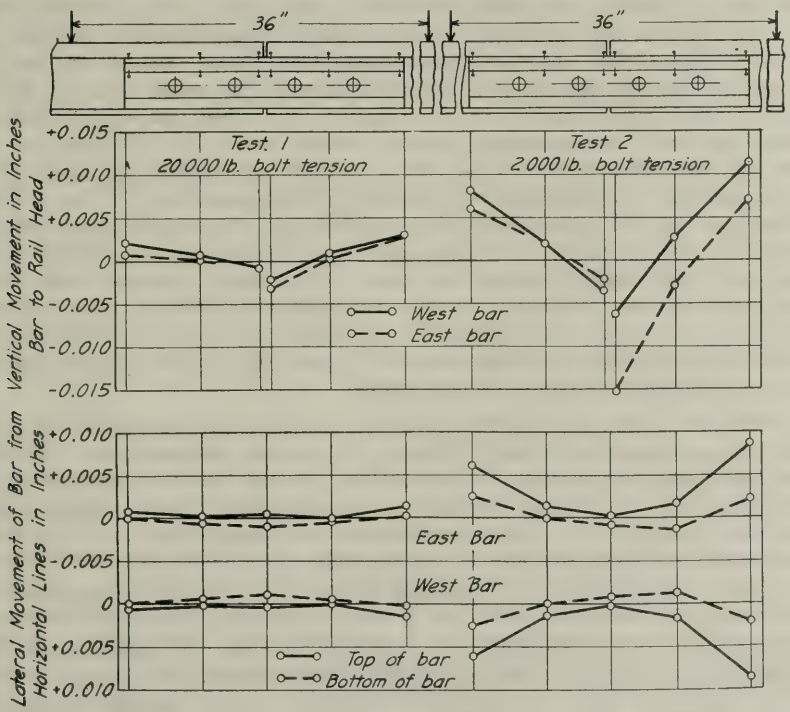


Fig. 14.—Vertical and Lateral Movements between Rail and Joint Bars along Their Length—Santa Fe Symmetrical Type Joint Bars for 130-lb. R.E. Rail—Bolt Tensions 20,000 and 2,000 lb.—Load 50,000 lb.

In Fig. 14 are shown the lateral and vertical movements of the joint bars with respect to the rail at five places along the length. Positive quantities mean an increase in a measurement between rail and bar (opening); negative quantities mean a decrease in the measurement (closure). The measurements of the lateral movements were made from one bar to the other and the two halves of the total movement are the values plotted in plan with reference to two straight lines indicating the initial position of the two bars. For a bolt tension of 20,000 lb., with a load of 50,000 lb. (two-point loading, giving a constant moment of 400,000 in.-lb. along the length of 36 in.) the lateral move-

ment of bars was slight, perhaps .001 in. or less outward movement at the top of the bar at mid-section. At other places the movement of the top was 0 or slightly outward; at the bottom of the bar, the movement was slightly inward along the whole length, perhaps .001 in. at mid-section, and less at other places. For a bolt tension of 2,000 lb., at top and bottom the bar remained close to its initial position throughout the middle 12 in. At the ends there was considerable movement outward averaging about .007 in. at the top and .002 in. at the bottom. The ends of the joint bars were thus not held closely by the end bolts and the bending of the rail at points near the end of the bar was instrumental in forcing the top corner outward.

The magnitude of the bolt tensions has a considerable effect upon the vertical movement between the rail and the joint bars. In Fig. 14 for the 20,000-lb. bolt ten ion and a load of 50,000 lb., the vertical movement is rather small. For the left half of the joint, the rail head and bars become closer together at the mid-section by less than .001 in. and at the end move apart for somewhat more than .001 in. For the right half, the fit was less close and the rail and bars moved closer at the middle by about .003 in. and at the ends moved apart by the same amount. For a bolt tension of 2,000 lb. the vertical movement was considerably greater. For the left half of the joint, the rail head and bars moved together about .003 in. at mid-section and moved apart .007 in. at the ends. For the right half the movement at mid-section was .015 in. closer for the east bar and .006 in. for the west bar and at the end .007 in. apart for the east bar and .011 in. for the west bar. The sum of the vertical movements at the four points (two ends of bar and two ends of rail) was .008 in. with the 20,000-lb. bolt tension and .030 in. with the 2,000-lb. bolt tension. The latter sum is somewhat above the value found in the tests of the best rail-joints in track heretofore made. It is evident that the higher bolt tensions will reduce the amount of vertical play between rail and joint bar and thus improve the quality of the joint action.

With the 20,000 lb. initial bolt tension, the tension in the inner bolts dropped off with both application and removal of loads, in decreasing amounts, losing 7,000 lb. in four applications, and thereafter remained fairly constant with more applications and removals of load. For the end bolts the loss in tension was 4,000 lb. in four applications, and little thereafter. It is evident that the bars were drawn closer to the rail by the bolt tension with each movement of the bar with respect to the rail (both vertically and laterally) and the accompanying flexure and recovery taking place at an application and a removal. With the 2,000-lb. bolt tension, the tension remains fairly constant in the inner bolts from the first application on through the series. The tension in end bolts increases by about 2,500 lb. at each application of load, resuming nearly the initial tension at each removal of load. This increase is in harmony with the outward movement of the end of the bars shown in Fig. 14 for 2,000-lb. bolt tension and may be contrasted with the lack of movement at the rail ends in the same diagram.

The measurements and test results show that this pair of joint bars do not fit the rail well, especially in one half of the length of the joint bars.

7e. **Norfolk and Western Continuous and Head Free Continuous Rail-Joints for 130-lb. P.S. Rail.**—Tests were made on unused Continuous and Head Free Continuous rail-joints received from the Norfolk and Western Railway to find the magnitude and distribution of stresses in joint bars, vertical and lateral movements between rail and bars, changes in bolt tension, and vertical and lateral deflection with unused 24-in. joint bars for 130-lb. P.S. rail. See Fig. 16 for the sections of the two forms of rail-joints

and the position of the gage lines and Table 2 for the properties. To distinguish between the two forms the regular Continuous will be designated as the head-bearing Continuous rail-joint and the other as the head-free Continuous rail-joint.

In Fig. 15 are plotted the stresses along the length of the bars near the top of the bar and at the outer edge of the bottom flange of the bar for bolt tensions of 15,000 and 2,000 lb., the diagrams at the left being for the head-bearing Continuous bars and those at the right for the head-free Continuous bars. The load of 50,000 lb. was applied in equal parts at two points 42 in. apart on a span of 74 in. in the case of the head-bearing

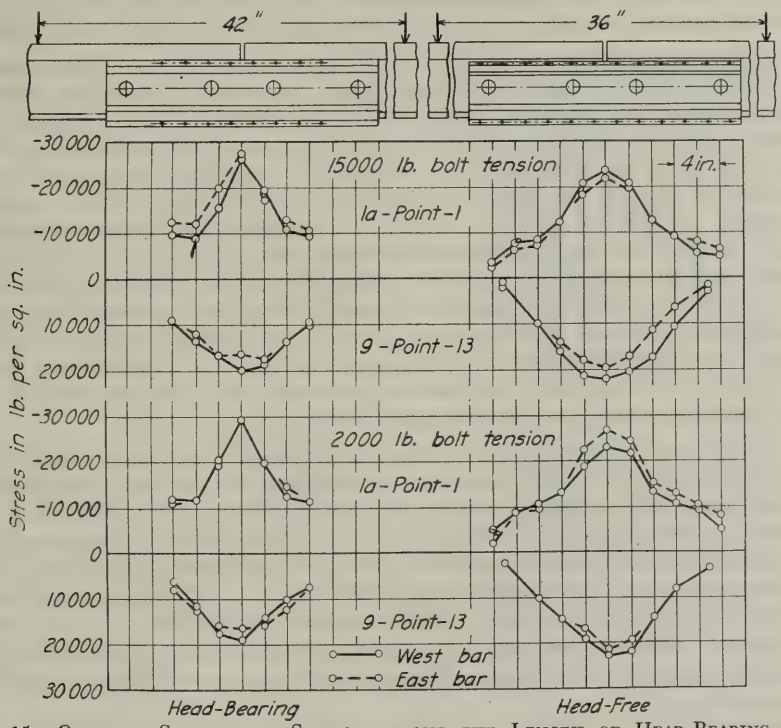


Fig. 15.—Observed Stresses at Sections along the Length of Head-Bearing and Head-Free Continuous Bars—Norfolk and Western Continuous Rail-Joints for 130-lb. P.S. Rail—Bolt Tensions 15,000 and 2,000 lb.—Load 50,000 lb.

Continuous rail-joint, and 36 in. apart on a span of 68 in. in the case of the head-free Continuous rail-joint, making an applied moment of 400,000 in.-lb. throughout the middle 42 in. and 36 in., respectively. For the head-bearing bars the compressive stress at mid-section in gage line 1a is 27,000 lb. per sq. in. with bolt tension of 15,000 lb., and 29,000 lb. per sq. in. with bolt tension of 2,000 lb., while at the bottom edge (gage line 9) the stress with both bolt tensions is 18,000 lb. per sq. in. At a section 4 in. away from the mid-section the stress at the top is only about 40 per cent of that at mid-section; the stress then drops slowly to the last gage line 2 in. beyond. For the head-free bars the stress at the gage line near the top of bar at mid-section (gage line 1) is 22,000 lb. per sq. in. with bolt tension of 15,000 lb., and 24,000 lb. per sq. in. with

bolt tension of 2,000 lb., while at the bottom edge (gage line 13) the stress is 21,000 lb. per sq. in. with both bolt tensions. At 4 in. away from mid-section the stress at the top gage line is 12,000 and 13,000 lb. per sq. in., respectively, with the two bolt tensions. The rounded or blunted shape of the compressive stress diagram in the middle 4 in. of the diagrams for the head-free bars, as compared with the more peaked nature of the same portion for the head-bearing bars, is an indication that the bearing of the rail ends on the head-free joint bar extends farther back from the rail end and the bearing load is distributed over a greater length than is the case with the head-bearing bars; probably too there is less bearing at the extreme end of the rails, since the tops of the head-free bars were found to have moved slightly outward from the rail at mid-length.

In Fig. 16 are plotted the stresses in each bar measured at 14 and 17 gage lines at mid-section for bolt tensions of 15,000 and 2,000 lb. for both head-bearing and head-free bars. A straight line represents the analytical stress distribution over the section calculated by the usual assumptions of beam action. For the two bolt tensions of 15,000 lb. and 2,000 lb., the measured stresses at the top of the two head-bearing bars are respectively 41 and 59 per cent greater than the analytical values, and the measured stresses for the head-free bars are 10 and 22 per cent greater than the analytical values. It will be noted that the stress in the head-bearing bars at gage line 1 is considerably greater than that at gage line 1a, the latter being the gage line used in the diagram in Fig. 15. As it is known that longitudinal stresses at and near a bearing area of high concentration of pressure are greater than at points some distance away from the bearing, it seems quite probable that the stresses in the head-free bar are greater as the fillet of the rail is approached and that the inaccessible part of the bar under the rail head has greater stresses than those measured at point 1.

The stresses across the lower face of the reflexed flange at mid-section (on the same horizontal plane) vary markedly and decrease considerably from the outer edge inwardly. In the head-bearing bars the stresses near the inner edge of the reflexed flange for a bolt tension of 15,000 lb. (gage line 13) are 7,000 and 10,000 lb. per sq. in. in the two bars, while the values next the outer edge (gage line 10) are 19,000 and 23,000 lb. per sq. in., as compared with the analytical value of 19,000 lb. per sq. in. for gage lines on the bottom face of the reflexed flange. Similar variations for the head-free bars are 10,000 lb. per sq. in. near the inner edge and 21,000 lb. per sq. in. near the outer edge at corresponding points, with an analytical value of 19,000 lb. per sq. in. on a basis of a horizontal axis.

Attempts to find an axis of plane bending which would result in stresses being proportional to the distance from the axis proved unsuccessful. The variations in stress at gage lines on the surface of the reflexed flange in both forms of joint bars were not in harmony with the stresses at the upper part of the section. The evidence points to a bending of the section within itself—particularly does the reflexed flange appear to bend independently of the rest of the section. It is plain that this part of the section (the reflexed flange) fails to take its share in resisting the applied bending moment for both forms of bar.

In the lower part of Fig. 17 are given the lateral movements at the top and bottom of the bars at five points along the length for both forms of bars upon application of a load of 50,000 lb. and an applied moment of 400,000 in.-lb., measured after enough applications had been made that upon removal of loads the bars came back very nearly to their initial position. Positive values represent increases in distance between rail and

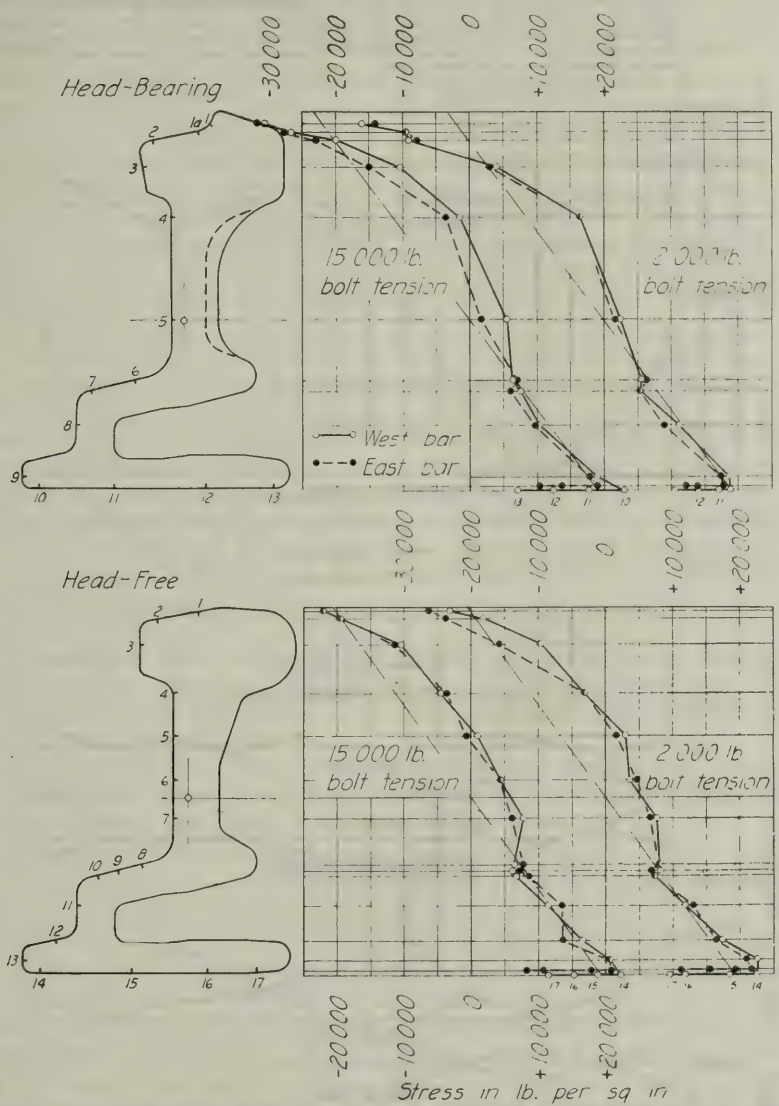


Fig. 16.—Observed Stresses at Various Gage Lines at Mid-Section of Head-Bearing and Head-Free Continuous Bars—Norfolk and Western Continuous Rail-Joints for 130-lb. P.S. Rail—Bolt Tensions 15,000 and 2,000 lb. —Load 50,000 lb.

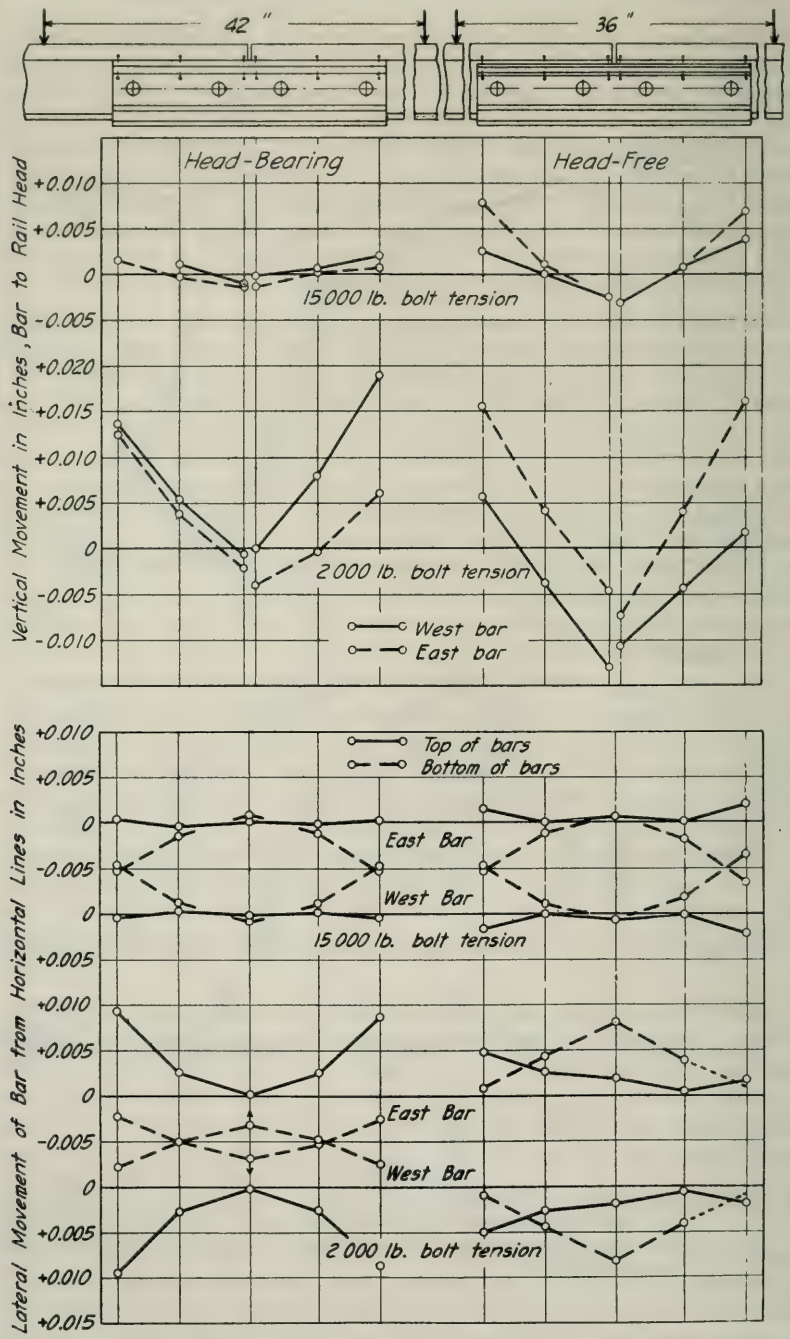


Fig. 17.—Vertical and Lateral Movement between Bar and Rail at Five Points along Their Length—Head-Bearing and Head-Free Bars—Norfolk and Western Continuous Rail-Joints for 130-lb. P.S. Rail—Bolt Tensions 15,000 and 2,000 lb.—Load 50,000 lb.

bar and negative values decreases (closure). The measurements in these tests were made from one bar to the other and the two halves of the total movement are the values plotted in plan with reference to two straight lines indicating the initial position of the two bars.

For the head-bearing bars, for both bolt tensions, at mid-section the top of the bar moved only slightly on application of load; the bottom of the bars moved outward, slightly with a bolt tension of 15,000 lb. (.001 in.), and inward .003 in. with a bolt tension of 2,000 lb. At the ends of the bars, with 15,000 lb. bolt tension, the top had very little movement and the bottom moved inward about .005 in.; with 2,000 lb. bolt tension the ends moved outward at the top about .009 in. and at the bottom inward .008 in. With the lower bolt tension there is then a considerable bending of the bars laterally outward at the top of the bars and their ends are bent inward at the bottom, showing a twist in the bars from middle to ends. Even with 15,000 lb. bolt tension the bottom of the bar was bent inward at the ends of the bar.

For the head-free bars, the top remains fairly free from lateral bending throughout its length, though there is a small reversal of flexure at mid-section; for a bolt tension of 15,000 lb. the lateral movement is slightly outward at mid-section, nothing or slightly outward at the quarter points, and .001 to .002 in. outward at the ends; for the tension of 2,000 lb. the lateral movement of the top is all outward, greater at the ends (from .002 to .005 in.) and about .002 in. at the middle; for the medium bolt tension the lateral movements measured are intermediate between those of the high and the low bolt tensions. The bottom of the head-free bars shows a marked curvature outward; for the bolt tension of 15,000 lb. the movement outward is slight at the middle (about .001 in.) and inward at the other points, having a maximum of .006 in. at one end; for the bolt tension of 2,000 lb., the bottom has about the same curvature in its length, but the lateral movement outward at the middle is quite large, say .008 in., while at the ends it is small; again, the action of the medium bolt tension is intermediate between those of the other two bolt tensions. With all bolt tensions there is twisting of the bar from middle to ends. It is seen that with the bolt tension of 15,000 lb. the two forms of Continuous bars have nearly the same lateral movement throughout the length, but that with the bolt tension of 2,000 lb. the amount of the lateral movement differs in the two cases. However, the character of the curvature is similar.

The vertical movement between bar and rail at six points along the bars upon the application of the load of 50,000 lb. is also plotted in Fig. 17 for the two bars of a joint as distances from a straight line representing the initial position for the two forms of Continuous rail-joint. For the head-bearing bars, with a bolt tension of 15,000 lb., at the rail ends the vertical movement is quite small, about .001 in. of closure at the four points; at the end of the bars, the movement is about the same amount but of opposite nature. With a bolt tension of 2,000 lb. considerably more movement occurs. At mid-section, one bar has little or no movement and the other bar shows .002 and .004 in. closure; at the ends of the bars the movement ranges from .006 to .019 in. opening. For the head-free bars, with a bolt tension of 15,000 lb., the vertical movements are markedly greater than those found with the head-bearing bars at the same bolt tension. At mid-section the movement shows a closure of .003 in. and at the ends of the bar an opening ranging from .002 to .008 in. Although these changes may seem small, vertical movements of this magnitude in track tests of other forms of bars have been found to accompany unfavorable conditions in the rail-joints. With a bolt tension of 2,000 lb. the vertical movements of these head-free bars become considerably greater,

but their magnitude is comparable with those found with the head-bearing bars at the same bolt tension. Measurements made with bolt tension of 8,000 lb. gave results intermediate between those with the two bolt tensions reported. It will be seen that the movement with the head-bearing bars and high bolt tension in the joint tested compares favorably with that for other forms of joint bars having similar bolt tensions and that the movement with the head-free bars under the same bolt tension shows considerably greater play.

The changes in bolt tension upon loading and unloading indicate a difference in action in the two forms of Continuous rail-joints. Fig. 18 records the changes in bolt tension with both forms of Continuous bars. With an initial bolt tension of 15,000 lb. the tension in the inner bolts of the head-free joint drops off abruptly on the first application of load in much the same manner as has been found in other rail-joints including the head-bearing Continuous rail-joint. With further applications there are slow decreases in tension in the inner bolts, but little difference between loaded and unloaded condition. The tension in the end bolts, though slowly decreasing, increases from the previous bolt tension in the unloaded condition by 2,000 and 4,000 lb. upon each application of load. An increase in the tension of the end bolts on application of load has frequently been found with other forms of joint bars at similar bolt tensions, but such increases have been small—not more than 500 lb. With initial bolt tension of 2,000 lb. the tension in the inner bolts of the head-free bars increased about 3,000 lb. with each application and that in the end bolts about 7,000 lb. The change in tension in the inner bolts is different in character from the action in other joints tested, including the head-bearing Continuous (see top of Fig. 18), for the change in tension in inner bolts has usually been a small decrease in tension, if any change; and the increase in the tension in the end bolts upon loading is unusual in amount, being several times that ordinarily found. It may be added that for both forms of the continuous joints the bolt tension changes are in harmony with the lateral movements of the bars.

Measurements of deflection under load were taken along three longitudinal lines or elements of the head-free Continuous bars extending over the length of the bar, one line through points at the top of the bar, one near the outer edge of the bottom of the reflexed flange and one near the inner edge of the reflexed flange. The three points through which these three lines pass are near gage line 1, 14 and 17, respectively, indicated on the section of the head-free bar in Fig. 16. For the bolt tension of 15,000 lb., the deflection at the middle of the line along the top of the bar was .017 in., that for the outer bottom line .008 in. and that at the inner bottom line .020 in. For the lower bolt tensions the corresponding deflections were .019, .010 and .022 in. The lack of uniformity in the three deflections is taken as one evidence that the section of the bar does not remain integral in bending.

Measurements with thickness gages showed that the bottom of the rail and the top of the reflexed flange in both forms of Continuous bars were not in contact at any point through the length of the bars, both when loaded and when unloaded.

The preceding discussion of the test results warrants the following comments on the action of the two forms of the Continuous rail-joint.

1. The longitudinal distribution of compressive stress for a set of gage lines a little below the top point of the head-bearing bar along its length is similar to that found with well-fitting bars of other types. The distribution of the corresponding stress with the head-free bar is less peaked (somewhat blunted), indicating a distribution of the top rail-bearing pressure along a greater distance back from the rail ends.

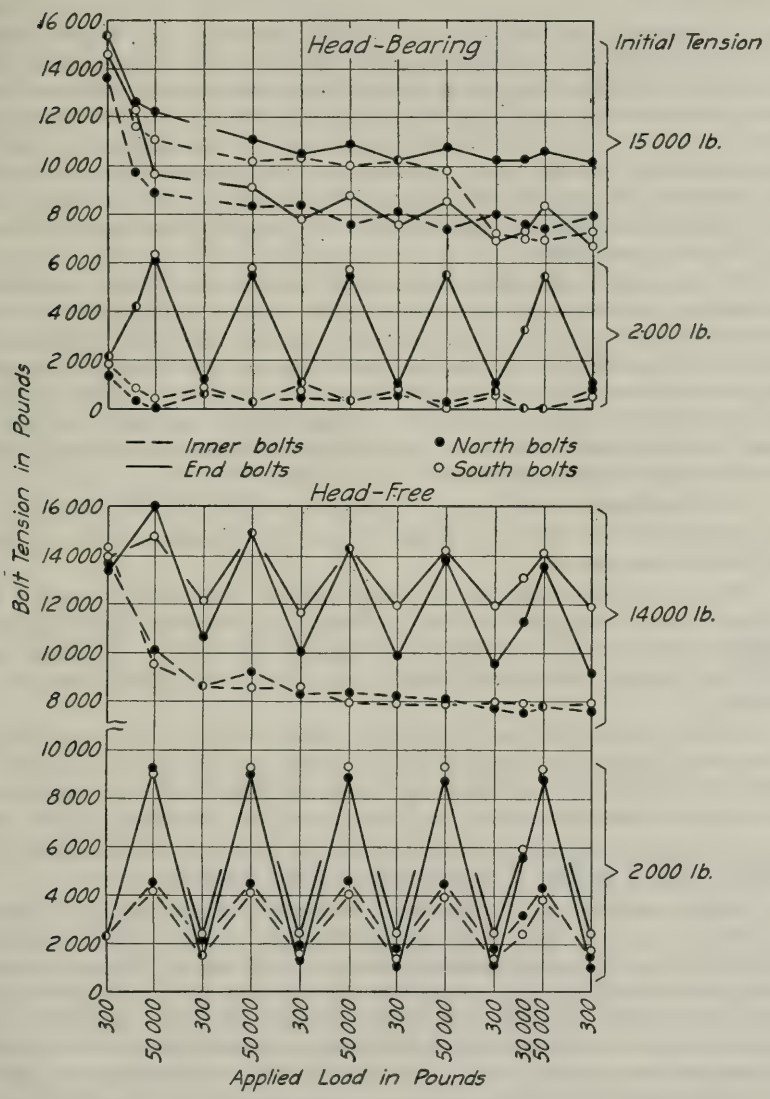


Fig. 18.—Changes in Bolt Tension with Repeated Application and Release of Load —Head-Bearing and Head-Free Continuous Bars—Norfolk and Western Continuous Rail-Joints for 130-lb. P.S. Rail—Bolt Tensions 15,000 and 2,000 lb.—Load 50,000 lb.

2. The measured stress at mid-section on the corresponding gage lines is 5,000 lb. less in the head-free bar than is found in the head-bearing bar. As the contact of the rail-bearing pressure in the head-free bar is well around on the fillet of the rail head and as the neutral axis of bending may be inclined negatively, it is not known where the maximum stress in the bar is located, nor to what extent the stress at the gage lines is decreased by the effect of the bearing pressure applied along the fillet of the rail head, and it is quite probable that a stress exists which is higher than the one measured at gage line 1. The measured stress in both forms of bars is considerably higher than the calculated stress of 20,000 lb. per sq. in. based on a horizontal neutral axis through the center of section. The measured stress at gage line 1a in the head-bearing bar is about 27 to 37 per cent more than the analytical stress and in the head-free bar at gage line 1 about 10 to 25 per cent higher.

3. The measured stress in the lowest fiber of the bars differed from the calculated value based on a horizontal neutral axis through the center of the section—in the case of the head-bearing bars it was about equal near the outer edge of the reflexed flange and about 50 per cent less near its inner edge, and in the case of the head-free bars about 15 per cent greater near the outer edge and about 50 per cent less near the inner edge. This indicates that the greater part of the reflexed flange is only partly effective in resisting bending moment in the manner assumed in ordinary beam analysis and that the bar does not have the full strength given by calculations.

4. The distribution of the measured stresses throughout the mid-section of the joint bars indicates that the reflexed flange does not act integrally with the remainder of the section during flexure.

5. For the head-free bars the stress at the bottom of the reflexed flange at one point near its inner edge (gage line 17 of section) is only less than half of the stress developed at the gage line on the same level near the outer edge of the flange (gage line 14), the relative values being 10,000 lb. per sq. in. and 22,000 lb. per sq. in. respectively.

6. For the head-bearing bar the vertical movement of the bar with respect to the rail was small and compared favorably with well fitting bars of other types. For the head-free bars at the higher bolt tension the vertical movement was greater, with closure in the distance between rail head and bar at the rail ends and separation at the bar ends.

7. For the head-free bars, the lateral outward movement of the bar at the rail ends indicated a change in position of rail-bearing contact upon application of load.

8. For the head-free bars the increase of tension in the inner bolts upon application of load (an action not found in other forms of bars) is in harmony with the observed lateral movement of the top and bottom of the bar at mid-section. Also, the increased tension in the end bolts was much greater than in other forms of bar, which corresponds with the large outward movement of the bars observed at the ends of the bars. High tension in the bolts causes both forms of rail-joints to act more satisfactorily—especially in the head-free bars. It follows that it is very desirable to maintain high bolt tension in the head-free form of rail-joint.

9. The observed stresses and deflections indicate that the section of the bar under bending load does not act fully integrally, and that the reflexed flange bends independently somewhat with respect to the remainder of the section.

10. The two forms of Continuous bars have heavy, sturdy sections, and though the whole area of the section is not fully effective in flexural resistance the stresses are relatively small. The placing of metal under the rail gives an opportunity of increasing

the section of the bar, but with this disposition some loss in effectiveness of the added metal must be accepted. With both forms of Continuous bars, it is essential that the fit between bar and rail be excellent.

7f. **Muller Rail-Joint for 130-lb. R.E. Rail.**—An unused Muller rail-joint for 130-lb. R.E. rail (drop-forged) received from the Baltimore and Ohio Railroad was tested for resistance to positive and negative moment. Fig. 19 illustrates the form of the bar in the rail-joint tested. The joint bars have a top bearing below the head of the rail for a length of 3 or 4 in. each way from the rail ends. On the base of the rails, a bearing extends for a length of about 3 in. from the two ends of the bar. From the drawing of the rail-joint it seems to be intended that there should be also a reaction bearing for a length of 4 or 5 in. each way from the mid-length of the bars and no bottom bearing contact between this and the end-bearing areas, but there was found to be no reaction bearing at the bottom of the bars throughout the length of the bar except in the end portions. The shape of the bar was such that a considerable tension was required in the end bolts to bring the bars to a bearing on the base of the rail at the ends of the bars, and there could be no bearing on the rail head near the bar ends. The inner bolts aid in holding the bar in place throughout its middle portion. The section is not uniform throughout the length of the bar; at the middle it is much heavier than at the ends. From the drawing it is apparently intended that the inner surfaces of the bar conform fairly closely to the rail contour over the whole vertical section of the bar throughout the middle part of the length.

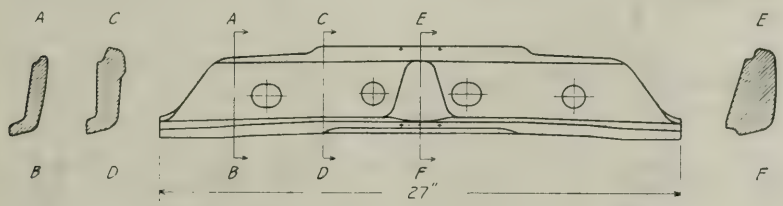


Fig. 19.—Muller Joint Bar for 130-lb. R.E. Rail.

The form of the rail-joint was such that under positive moment the bearing pressure of the rail head is applied at the top of the joint bars near the rail ends as in the ordinary forms of joint, and the reactions of the bars on the base of rail are applied entirely at the ends of the bar. The high tension put into end bolts in forcing the ends of the bars into place bent the bars laterally and put high initial bending stresses into the fibers of the bars, especially in the extreme outer fibers of the bottom portion of the section at mid-length, as will be seen from the results of the test. The tightening of the end bolts also lifted the top bearings at the rail ends with respect to the level of the reaction bearings at the ends of the bars—in other words it produces a camber in the rail-joint from points on the rail beyond the end of the joint bars. It will be seen that upon the application of negative moment the reaction at the top of the bar can be applied on the top fishing surface of the bars at areas only between 3 and 4 in. from the ends of the rail and that there must be considerable vertical movement between bar and rail before resistance to negative moment will be available in any way.

In the tests of the Muller rail-joint the loads were applied at the middle of a 48-in. span, the maximum load being 25,000 lb. and maximum bending moment 300,000 in.-lb.

In Fig. 20 the stresses at the mid-section near the top (gage line 1, see Fig. 19) and at the extreme outside edge of the bottom flange (gage line 10) are plotted for loads of 8,300, 16,700 and 25,000 lb. on the first application of positive moment, and for the fifth application of 25,000 lb. The stresses shown are seen to be proportional to the loads. In the first loading the stresses at the top gage line for the load of 25,000 lb. are 27,000 and 40,000 lb. per sq. in. in the two bars (compression) and 2,000 and 10,000 lb. per sq. in. at the bottom gage line (tension). On the fifth application of 25,000 lb. the stresses in the two bars were 30,000 and 42,000 lb. per sq. in. at the top gage line and 1,000 and 8,000 lb. per sq. in. at the bottom gage line. The rail-joint was then turned over and loads of 8,300 and 12,500 lb. were applied, developing negative moments of 100,000 and 150,000 in.-lb. at mid-span. Considerable deflection was developed on the application of load. On the first application of the load of 12,500 lb. the stresses were 17,000 lb. per sq. in. tension at the original top gage line (gage line 1) and 1,000 lb. per sq. in. tension at gage line 10. All the above values were obtained by using the original zero of measurement, although in the application of the several loadings the readings in the unloaded condition indicated variations in the stress condition, due doubtless to changing adjustments of the bar with respect to the rail throughout the length of the rail-joint.

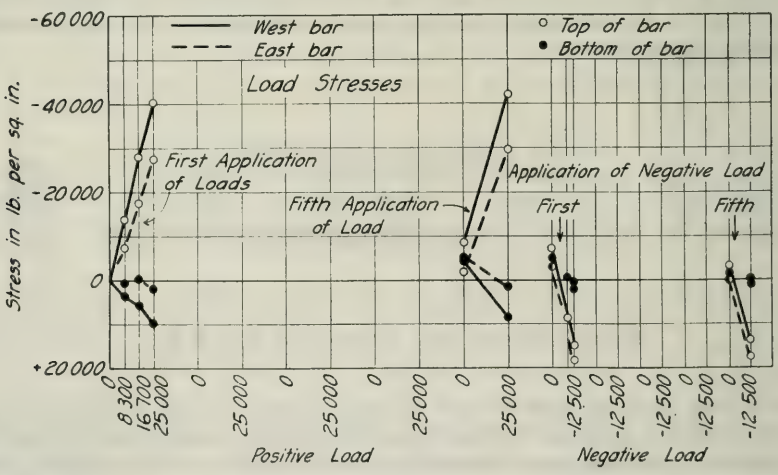


Fig. 20.—Observed Stresses at Mid-Section of Joint Bars near Top of Bar and at Extreme Outside Edge of Bottom Flange on Application of Load. Positive Load of 25,000 lb. and Negative Load of 12,500 lb. Each Repeated Five Times—Muller Rail-Joint for 130-lb. Rail.

A tension of 29,000 and 17,000 lb. had been applied to the two end bolts in assembling the joint. The bolts were loosened at the end of the tests described above and strain gage readings were taken. The results show that initial tensile stresses of 31,000 at the top (gage line 1) and 74,000 lb. per sq. in. at the bottom (gage line 10), due to the initial tightening of the bolts, existed in the bars in the assembled condition of the rail-joint, assuming that the elastic limit is not exceeded. In Fig. 21, these initial stresses have been taken into consideration and the total resultant stresses, based on the original loosened, unstressed condition of the bars with bolts loose, are shown for each gage line

for each application and release of load. The values shown in the figure are then the sum of the stress due to bending the bars in tightening the end bolts and that due to loading the joint. On the application of the load of 25,000 lb. to the assembled joint the actual stress at the top gage line, which had an apparent average compressive stress of 34,000 lb. per sq. in. as shown in Fig. 20, actually has a resultant compressive stress of about 3,000 lb. per sq. in. as shown at the bottom of the figure, and the bottom gage line, which had an apparent tensile stress of 6,000 lb. per sq. in., has an actual tensile stress of 80,000 lb. per sq. in., again assuming that the elastic limit has not been exceeded. It is seen that the initial stresses put into the bar by tightening the end bolts have

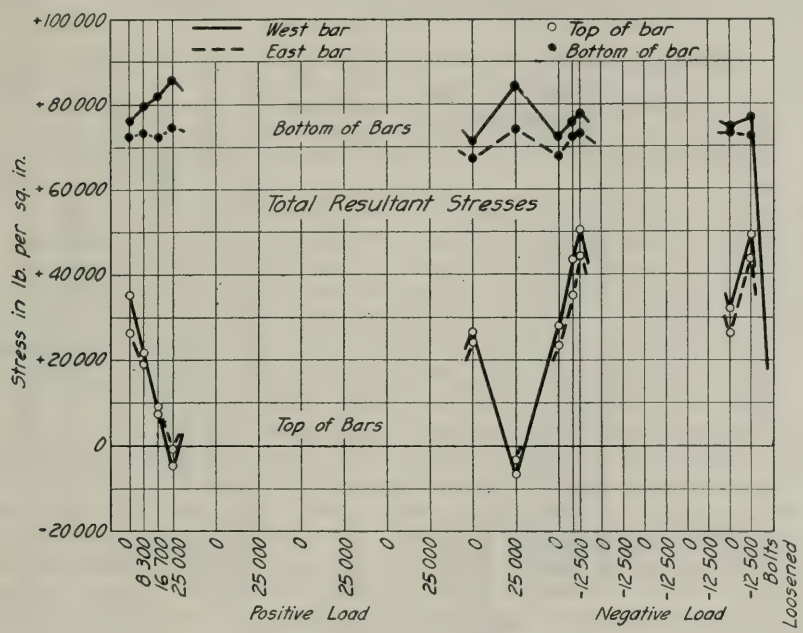


Fig. 21.—Total Resultant Stresses at Mid-Section near Top of Bar and at Extreme Outside Edge of Bottom Flange, Including Assembly Stresses and Load Stresses—Positive and Negative Loading—Muller Rail-Joint for 130-lb. Rail.

greatly changed the resultant stresses present under the applied load. Under the application of negative moment the initial stresses at the top of bar are increased by 16,000 lb. per sq. in., and those at the bottom gage lines are increased about 2,000 lb. per sq. in. The stresses given in Fig. 20 and 21 are based on the assumption that the elastic limit of the metal has not been exceeded.

In assembling the rail-joint, on the tightening of the end bolts to the tension of 29,000 and 17,000 lb. per sq. in. the rail ends at the middle of the joint rose from a straight line joining two points 48 in. apart up to a height of .125 in. The deflections at mid-span are given in Fig. 22. The deflection upon application of load of 25,000 lb. was almost the same as the camber put into the 48-in. length by the tightening of the

bolts. This deflection of .125 in. is very much more than that obtained with the same load with the other joints tested and reported in this article.

On application of negative moment the deflection was marked, .2 in. in the center of a span of 48 in. for load of 12,500 lb. and negative moment of 150,000 in.-lb. The play or movement in unloaded conditions between the position on the release of the positive moment of 300,000 in.-lb. and that on the release of the negative moment of 150,000 in.-lb. was .15 in. In other words, the middle of the span of 48 in. would move .15 in. after the release of positive moment before the joint would take negative moment. It is evident that under track conditions the rail-joint is not likely to move upward sufficiently to give negative resistance and thus a negative moment would not ordinarily be developed in the track under usual conditions.

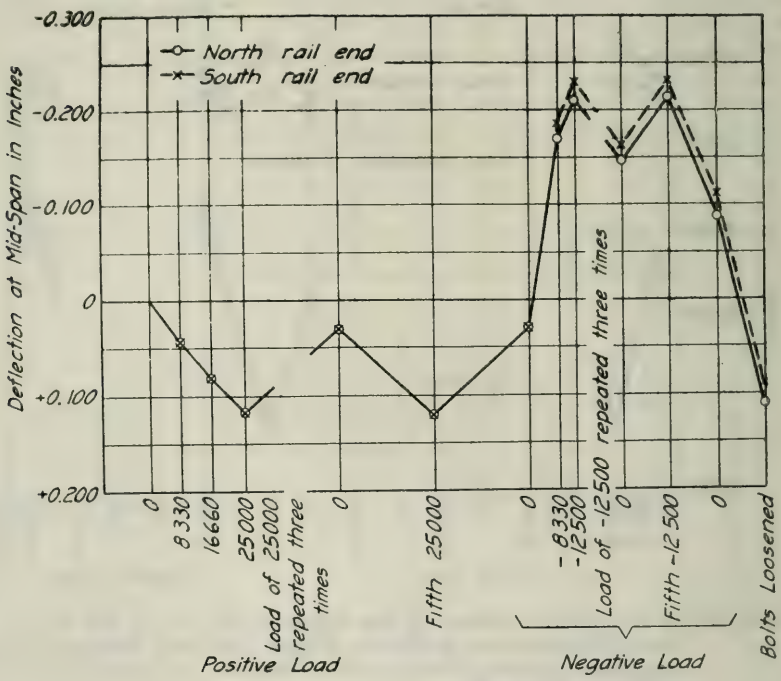


Fig. 22.—Deflection at Middle of Span of 48 in.—Muller Rail-Joint for 130-lb. Rail—Positive Load of 25,000 lb. and Negative Load of 12,500 lb. Each Repeated Five Times.

The relative vertical movement between the bars and the rail on application of load was measured. At mid-section the distances to the heads of the rail ends decreased by .003 in. for the load of 25,000 lb. At the ends of the bars the increase ranged from .002 to .009 in. at the places where bearing contact was obtained in the assembly of the joint, the latter movement being much larger than those reported for the other rail-joints. The movement varied somewhat with the load. When the positive moment had been released and the negative load of 12,500 lb. had been applied the first time, the vertical movement between bar and rail amounted to .015 in. at mid-length and .050 in. at the ends. Much of this movement occurred before the joint took moment,

and on release of negative moment the bars failed to return to the first position by .012 in. at the middle and .038 at the ends.

For the middle portion of the length there was no contact between the under side of the bars and the base of rail in either the loaded or unloaded condition, as found by observation with thickness gages, and consequently there was no reaction bearing in this portion of the length of the bars and the reaction forces were limited to the areas near the ends of the bars.

It should be noted that the maximum load applied to this rail-joint was only 75 per cent of the maximum loads applied to the other rail-joints discussed in the laboratory tests, this limitation being made because it was desired not to overstress the bars.

The exceedingly high initial stresses put into the bars through tightening the end bolts to bring the end bearings into working position and a further increase in stress at the lower gage line on applying load, which were found in the rail-joint tested, emphasize the need of exercising control of the form of the bar longitudinally in its design and manufacture in order to limit the stresses developed in the bar by installation and use.

8. **Action of a Rail-Joint under an Advancing Load.**—The laboratory tests on rail-joints have usually been made either with a single load applied at the middle of a simple span or with two loads placed symmetrically with respect to the rail-joint and the beam supports. With a view to learning the changes in the action of the rail-joint as a load advances toward the rail-joint and passes on over it, a series of tests was made on a number of rail-joints by applying a single load at the middle of a 48-in. span and moving the load and supports along the length of the structure by increments of 6 in. for succeeding tests in an effort to simulate to some degree the action of a moving wheel load along the track. Although the method of supporting the rail is quite unlike the reaction support of ties and ballast in track, the form of the moment curve is not unlike that developed in track and the tests approximate closely enough to successive actions of the rail-joint in track to give significant information. One purpose of the tests was to see if evidence could be obtained of any sudden changes in the deflections, movements, or stresses within the rail-joint that would produce undesirable accelerations or impacts as the wheel approaches and passes over a rail-joint. These tests were made in advance of the measurement of stresses in joint bars under rapidly moving loads in the tests on the Pennsylvania Railroad at Claymont, Delaware, and the information gained was also of value in planning these moving load tests in track and in interpreting the results.

The laboratory tests with advancing loads were made on three forms of rail-joint—(1) the New York Central rail-joint for 127-lb. N.Y.C. rail and 38-in. angle bars, (2) the Santa Fe rail-joint with 130-lb. R.E. rail and 26-in. bars of near-symmetrical section, and (3) the Illinois Central rail-joint for 90-lb. A.R.A.-A rail and 24-in. angle bars. The sections of the joint bars are shown in Fig. 3 and also the position of the gage lines, except that of the I.C. joint, which is shown in Fig. 25 of the Fifth Progress Report. The properties of the joint bars are given in Table 2. The first and the last mentioned joints were described in the Fifth Progress Report. The Santa Fe joint bar has the same section as the joint bars used in the tests on the Chesapeake and Ohio Railway at Ashland, Kentucky, though the latter have a length of 39 in. Generally, tests were made on two or more joints of each form and in several instances the tests were repeated or made a second time in a different way. However, the principal tests of each form of joint were made on one joint. Considerable time was given to these tests, as the procedure was time consuming.

The N.Y.C. rail-joint tested showed excellence of fit and little play between joint bar and rail throughout. The test results were very consistent and the uncertainties few. The tests were made after work had been done with the other rail-joints and were carried out in greater detail. For these reasons the tests of N.Y.C. rail-joint will receive the greatest attention.

In the principal test of the N.Y.C. rail-joint made with advancing load, the joint was first inverted and a negative load of 13,300 lb. (40 per cent of the moment applied to the rail-joint in each of the positive loadings) was first applied at mid-length of the joint (designated as *A* in Fig. 23) with the reaction supports placed 24 in. each way. The regular load of 33,300 lb. was then applied positively (downward with respect to the ordinary position of the rail) at a point 24 in. to the left of mid-length of the joint (*B* in Fig. 23) and with the supports 24 in. each way, the right reaction thus being at mid-length of the joint. The next loading was made with the load and supports moved 6 in. to the right (*C*), followed with successive similar loadings 6, 12, and 18 in. farther to the right (*D, E, F*) (the last mentioned being at mid-length of joint) and then others at 6, 12, 18, and 24 in. to the right of mid-length of joint (*G, H, I, J*). The joint was then reversed in vertical position and a negative load of 13,300 lb. again applied at the middle (*K*). The bolt tension in this set of tests was nominally 20,000 lb. Stresses were measured at nineteen 2-in. gage lines along the top of the angle bars (gage line 1) and at the same number along the outer edge of their lower flange (gage line 8).

The moments developed in the various sections of the bars have been calculated from the stresses observed at the top and bottom gage lines by equation (67) given in Article 4 "The Function and Action of the Rail-Joint", which takes into account the inclination of the neutral axis. This equation expresses the relation between the vertical bending moment and the stresses at two gage lines in the section. The values of the moments in the two bars thus obtained are plotted in Fig. 23 for the eleven loadings, and inspection of the diagrams will show that with one reaction support at mid-length of joint (either the right or the left one, *B* or *J*) the greatest moment in the bars was at 8 or 10 in. from mid-length—about 8 per cent of the maximum moment developed at mid-section with the load over it; the moments in the half of the bar in this loading are evidently developed with the bending of the rail itself and no moment is carried by the bars to the other rail. For all other loadings the maximum moment in the bars is at their mid-section. For positions of the load other than the end position and the one at mid-length there is generally a hump directly under the load, more or less pronounced; it is evident that this is occasioned by the greater curvature developed in the rail directly under the load and the corresponding changes in the positions of the vertical forces which apply load to the bars.

In Fig. 24 the moments developed at thirteen sections by the various loads are plotted as influence lines—that is, for each of the thirteen gage lines the moment corresponding to each of the nine positions of the load is given. The position of the load which gives the plotted moments at the several sections along the length of the bar (mid-section, 2 in. left, 2 in. right, etc.) is indicated by the letters *B, C,* etc., which correspond to the positions of load shown in Fig. 23. To conserve space, the values for sections at the left of the mid-length of the joint and at the same distance to the right are plotted together for common positions of the loads. It will be noted that the corresponding gage lines in the two halves of the joint have values of the moments nearly the same in amount for corresponding relative positions of the load. For all those gage lines having the load directly over it this position of load gives the greatest moment for the given section, and this would probably be true for the other gage lines if loads had been placed

immediately over them. The changes in moment are uniformly gradual; there is no evidence that further increases would be caused by impact or obstructed acceleration.

The distribution of the negative moment along the length of the bars (see Fig. 23) shows a rounded instead of a peaked shape at and near mid-section. It is stated elsewhere that the data of lateral movement of the bars under load show a slight outward movement at mid-section, and the load applied by the rail base on the bottom of the bars (negative bearing pressure) evidently extended farther away from the rail ends than was the case in the positive loading and thus the resultant of the bearing pressures was farther from the rail ends. In other respects the distribution of moments along the bars is similar to that with the positive loading.

In this N.Y.C. rail-joint for the same loadings measurements were taken of lateral movement between rail and bars at both top and bottom for points at ends of bars, at the mid-length for each rail end, and at 6 in. and 12 in. each way from mid-length. These measurements for positive loadings show that at the rail ends the bottom of the bar moves inward slightly when the load reaches a point producing a positive moment in the bars at mid-section (load 18 in. from middle of joint), the movement increases as the load advances and the moment increases, and it becomes a maximum when the load is at mid-length; the lateral movement at mid-length then decreases as the load passes over the joint becoming negligible as the moment developed is negligible. The value of the lateral movement at the bottom of the bar along its length ranged from less than .001 in. when first measurable to a maximum of .002 in. This inward movement is partly attributable to the inward pull of the inner bolts while the bottom of the bar is freed from initial contact with the base of rail when moment is developed at mid-section and naturally may be greater with unsymmetrical sections. At the same time the top of the bar at mid-section moved slightly outward a maximum of .0005 in. as measured when the load reached mid-length. At other points the lateral movements were all small except that when the load had advanced past the mid-section the corresponding ends of the bars at both top and bottom moved outward a maximum of about .0015 in.

Vertical movements between rail and bars upon application of load were measured at the same eight points. These movements are all quite small, ranging from 0 to .001 in., and the fit between rail and bars is correspondingly close. In the case of the negative moment (40 per cent of the positive moment) the vertical movements between rail and bar are still smaller—all of them under .0005 in. Fig. 25 shows influence lines for vertical movement between rail and bars at one-half inch each way from mid-section, at sections 12 in. each way from mid-section, and at ends of bars, each for the positions of load indicated at the top of the diagram. The measurements show that as the load advanced along the rail-joint the vertical movement at mid-section (closure) increased, becoming .001 in. with the load over the rail ends, and then decreased with further passage of the load. With the load at the approach end of the bars, a separation between rail and bar began as the load advanced beyond the first bar end, then decreased as the load advanced; a similar opening on the farther end began when the load had advanced to within 6 in. of mid-section, then increased, and finally closed as the load passed beyond the farther bar end. These differences in vertical movement between rail and bar are due to the difference in curvature of rail and bar as the load passes along—when the load is 12 in. left of mid-section the curvature of the rail in that vicinity is a maximum and that of the bar is small so that the bar end necessarily is deflected downward from the rail head, and a similar movement takes place at the far end when the load has advanced to that half of the joint. When the load is near mid-section the curvature of

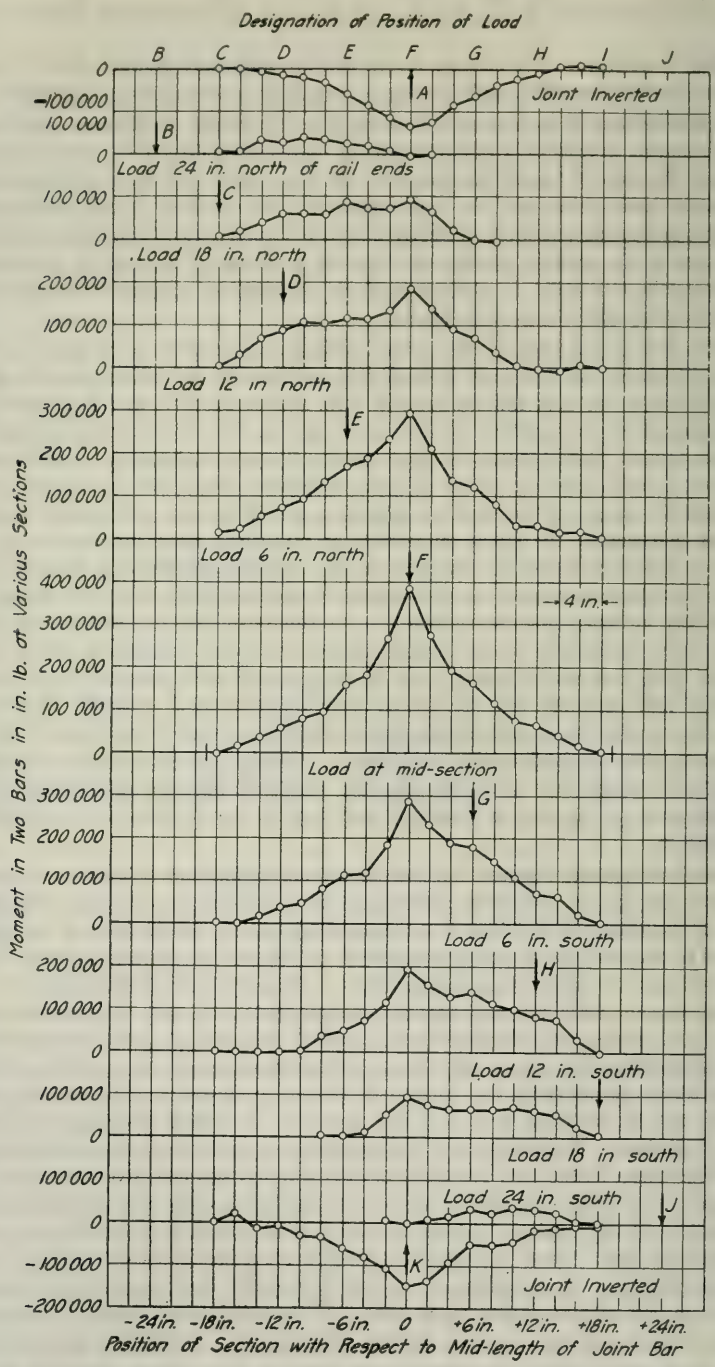


Fig. 23.—Moments in Two Bars at Various Sections on Applying an Advancing Load along a Rail-Joint—N.Y.C. 38-in. Angle Bars for 127-lb. Rail—Load of 33,300 lb. at Middle of Span of 48 in.—Also for a Negative Load of 13,300 lb. at Mid-Length of Joint.

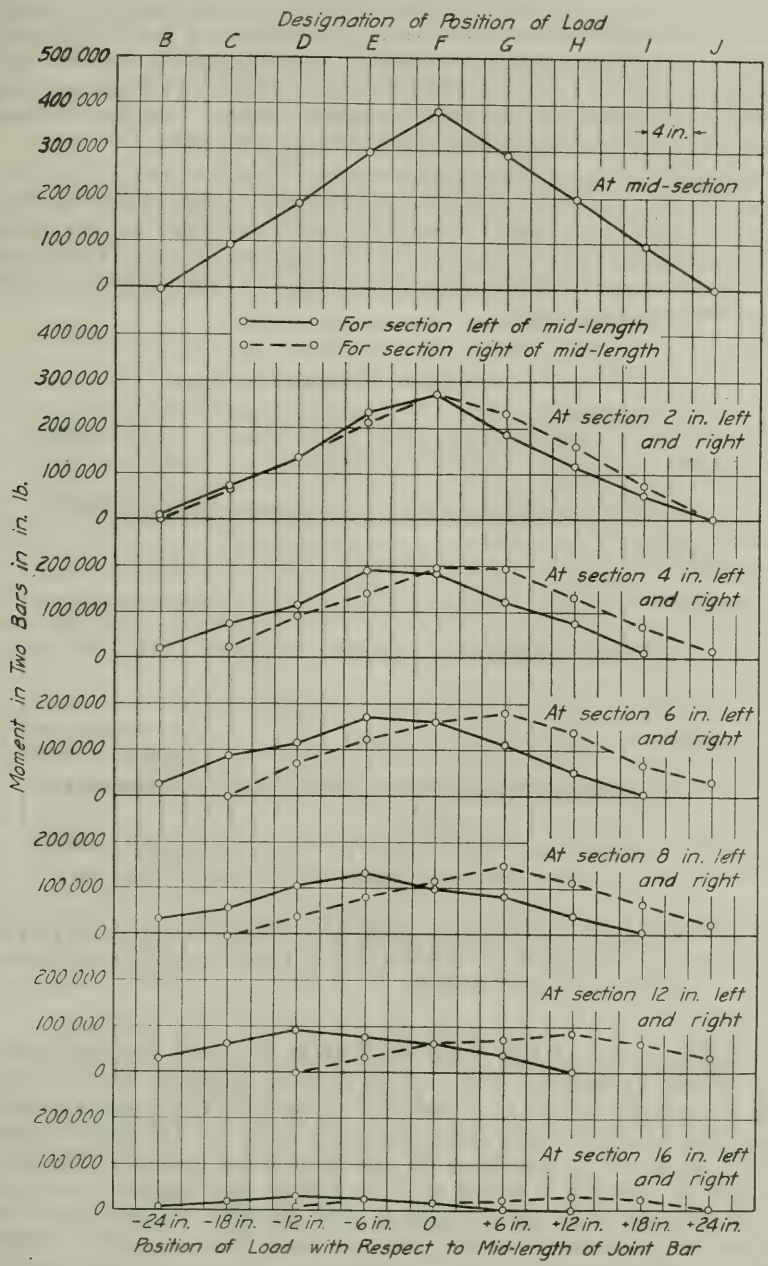


Fig. 24.—Influence Lines for Moments in Two Bars at Various Sections for an Advancing Load along a Rail-Joint—N.Y.C. 38-in. Angle Bars for 127-lb. Rail—Load of 33,300 lb. at Middle of Span of 48 in.

the rail near its end is a minimum and that of the bar near mid-section is a maximum so that the rail ends must bear heavily on the top of the bar, in fact this difference in curvature of rail and bar and the differences in their direction are the source of the "digging in" of the rail end at the fishing surface of the bar. While these movements and differences are small, they are very significant in relation to the wear and cutting of the metal and are encountered in much greater degree in the track.

The deflection of the rail and rail-joint in 48 in. with the load of 33,300 lb. at mid-length of joint was .050 in., as compared with .030 in. calculated deflection for full rail. With the load and supports moved 6, 12, and 18 in. either way the measured deflection at mid-span was .042, .034, and .035 in., respectively. Because of the excellence of the fit, the increase in deflection due to the presence of the rail-joint was smaller than has ordinarily been found.

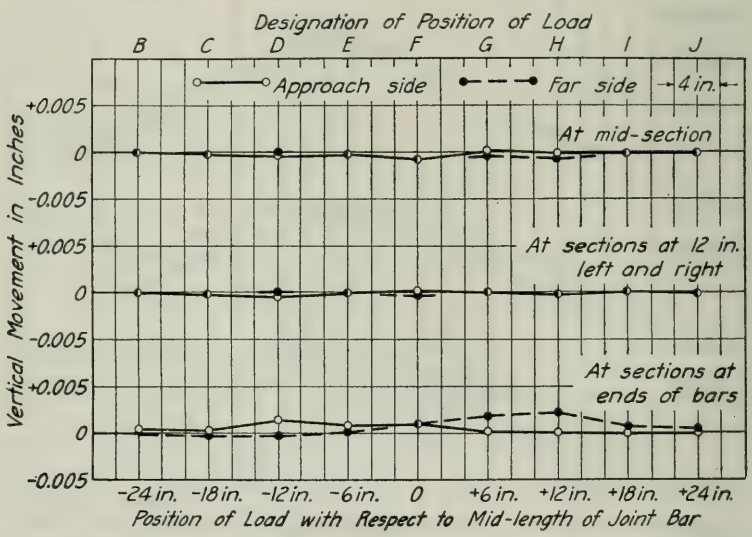


Fig. 25.—Influence Lines for Vertical Movements between Rail and Bars at Six Points along the Length of the Rail-Joint on Applying an Advancing Load—N.Y.C. 38-in. Angle Bars for 127-lb. Rail—Load of 33,300 lb. at Middle of Span of 48 in.

Using bolt tensions of both 20,000 and 2,000 lb. tests were also made with the N.Y.C. rail-joint by applying a load of 33,300 lb. at the middle of the joint and then moving the load and supports 6, 12, and 18 in. to the left. The measured stresses for the load over the rail ends have already been given in Fig. 6. The moments observed in the bars at mid-section were closely the same for both bolt tensions, as were also the moments in the joint bars at sections under the load for other loadings. The observed moments at sections in the right halves of the bars, especially at a right support, were larger with the bolt tension of 2,000 lb. than those found with bolt tension of 20,000 lb. for loadings other than at the middle of the rail-joint. This surplus of moment in the joint bars was present from even beyond the right support. The lateral movement at mid-section at all loadings with advancing load was considerably greater with the low

bolt tension than with the high bolt tension. The vertical movements between rail and bar were somewhat greater with the low bolt tension, but the difference was not as great as has been found with other rail-joints tested.

For the Santa Fe rail-joint (symmetrical section, length 26 in.) an advancing load of 33,300 lb. was applied at a load point 18 in. to the left of the middle of the rail-joint with a span of 48 in., followed by applications of the load at 12 and 6 in. to the left of the mid-section, at mid-section, and 6, 12, and 18 in. to the right of the mid-section. A negative moment equal to 40 per cent of the positive moment was applied before and after the loadings named. In Fig. 26 are plotted the moments at eleven sections observed under these nine loadings. The same designation is used for indicating the position of the load with respect to the rail ends as was used in Fig. 23. For the load 18 in. left of mid-section (load at *C*) the moment measured at mid-section of bars was 110,000 in.-lb., about the amount of the applied moment at that point in the span. For load at 12 in. left of mid-section naturally no moment was developed in the bars immediately under the load. This is of course in contrast to the moment developed in the N.Y.C. 38-in. bars at a section 12 in. left of mid-section with the load applied above that section; the moment developed in the bars at this section was 80,000 in.-lb., which is 40 per cent of the moment developed at mid-section with the same loading and a third more than the moment at this section with load at mid-length, a condition that is caused by the accompanying bending of the rail itself immediately above this section. A similar comparison holds with a load 12 in. to the right of mid-section. It is seen that with an advancing load the longer bars take moment in the first third of the half length of the bar (even greater than is developed at these sections remote from mid-section as the load moves along to mid-section and beyond), whereas in the shorter bars it is not possible, of course, to develop moment at a section at the ends of the bar. The shorter bar shows the same tendency to increased moment under the load as the load moves along that was found in the longer bar of the N.Y.C. rail-joint, although the hump is less pronounced and may be somewhat masked by differences in fit. The influence lines for moments in the Santa Fe rail-joint (not plotted) are quite similar to those given for the N.Y.C. rail-joint, but the difference in fit at the two halves of the Santa Fe joint bars renders the influence lines for corresponding sections in the two halves of the length less consistent than shown in the Fig. 24. The vertical and lateral movements between rail and bars are likewise similar to those of the N.Y.C. rail-joint, though naturally on the looser half of their length the movements measured are somewhat larger.

Tests were made with I.C. rail-joint No. 3 (other tests with this rail-joint were reported in Fig. 35–39, 46–50 and 56–57 of the Fifth Progress Report) by applying loads at mid-section and at 6, 12, and 18 in. left of mid-section, bolt tensions of 20,000 and 2,000 lb. being used. This rail-joint was a used joint, somewhat worn, and only one of the rail ends was the original rail. The fit between rail and bar for the right half of the joint was poorer than that for the other half, and the difference showed up in differences in stresses and in vertical movements in the two halves of the bars. In moment distribution diagrams of these tests (not given), the moments in the left half of the bars drop off quickly from the value at the mid-section, as is usual with well fitting bars, whereas those on the right half sloped gradually to nothing near the right end, showing that the reactions of the right half were nearer to the ends of the bars than usual. At the section 6 in. left of mid-section in tests with bolt tension of 20,000 lb. there was a noticeable hump in the moment distribution diagram, as was found in the N.Y.C. and Santa Fe rail-joints tested with advancing loads. This hump was not present in tests with a bolt tension of 2,000 lb., the looseness evidently giving a chance for adjustment

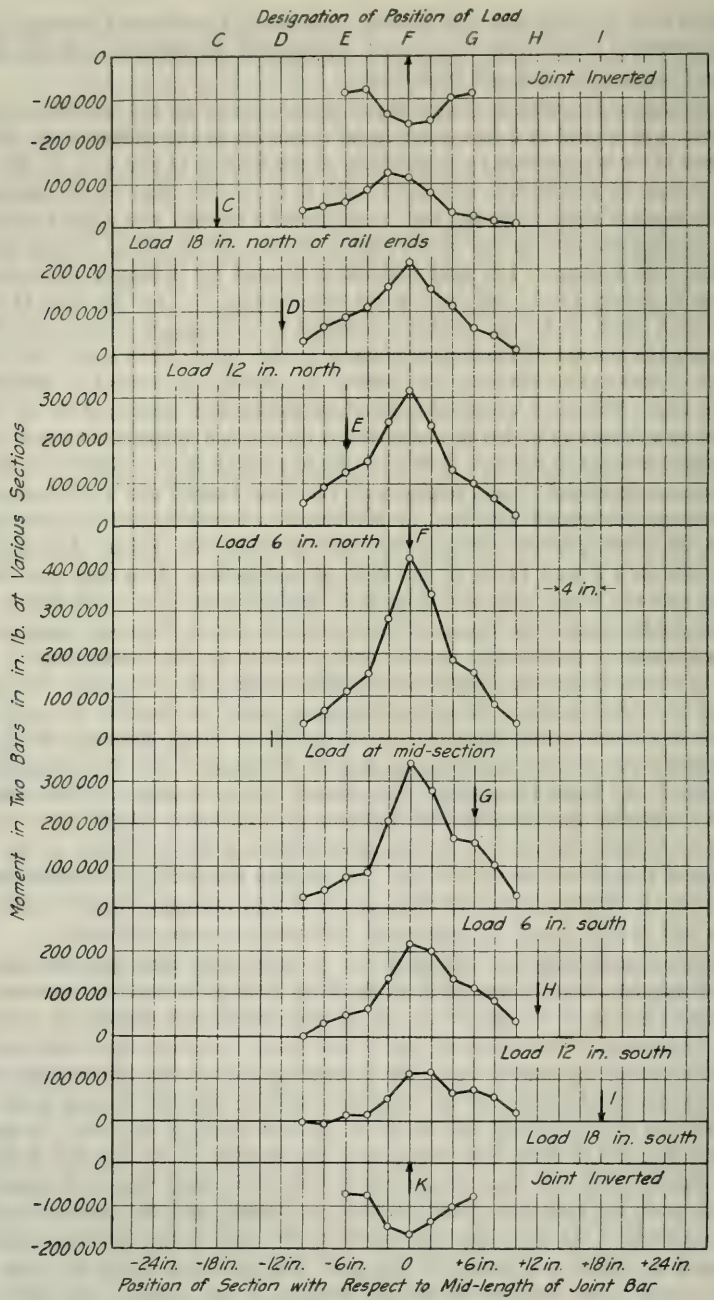


Fig. 26.—Moments in Two Bars at Various Sections on Applying an Advancing Load along a Rail-Joint—Santa Fe Symmetrical Type 26-in. Joint Bars for 130-lb. R.E. Rail—Load of 33,300 lb. at Middle of Span of 48 in.—Also for a Negative Load of 13,300 lb. at Mid-Length of Joint.

between the curve of the rail and that of the bar, otherwise the moment distributions for the two bolt tensions show similar results. The vertical movement between rail and bar was much greater for the right half of the bars than for the left half, and was considerably greater for the 2,000-lb. bolt tension than for 20,000 lb. For the load at mid-section, the greatest vertical movement between the end of the left rail and the bar was .001 in. for the higher bolt tension and .0015 in. for the lower bolt tension, while for the end of the right rail the movement was .005 in. for the higher bolt tension and .009 for the lower one. This movement gradually decreased to nothing as the load receded from the middle of the joint and the moment at mid-section decreased. The vertical movement at the bar ends on application of load at the mid-section was .002 in. and .007 in. for the two bolt tensions and gradually decreased as the load receded from the middle of the joint.

In the Fifth Progress Report (page 229) tests of rail-joints in the track of the New York Central Railroad with the passage of a wheel load away from the joint are described, but the moments developed along the joint bars were not reported. A summary of the findings of the test in this track may be useful in making comparisons with the results of laboratory tests with advancing load. The moments developed in joints 37 and 43 at mid-section were reported in Fig. 95. Both joints have 38-in. angle bars for 127-lb. rail. Joint 37 evidently had scant supporting reactions by the joint ties and developed a high moment at mid-section; its bolts were not very tight but the bars were fairly well-fitting. Joint 43 had hard tie supports and the moment at mid-section was much smaller; five of the six bolts were loose and there was rather large play between rail and bar. The rear wheel of the loaded car was placed at mid-length of joint and then the car was moved ahead 8, 16, 24 and 32 in. successively. In both joints the moment distribution along the bars for load at mid-length of joint was similar to that found in laboratory tests, if differences in bolt tension and the effect of the second wheel are taken into consideration. For joint 37, the left half of the bars (that is, the half farther away from the inner wheel) was peaked, as has been found in the laboratory tests, for all the positions of load. In the right half, as the load moved along, the moment was less at mid-section than at 2 in. to the right, and the moment at the section 8 in. to the right (although less than the moment at mid-section) decreased much more slowly than did the moment at mid-section as the wheel moved off the joint, thus giving an approach to a straight line distribution in the right half for all positions of the load. A condition somewhat similar existed in the right half of the bars of joint 43. In both joints the sum of the moments in rail and two bars at various sections along the joint agree in form with that observed in the full rail opposite the joint for corresponding positions of the load.

9. **Effect of Combinations of Tight and Loose Bolts.**—Tests were made to find effects of loosening part of the six bolts in angle bar rail-joints. A N.Y.C. rail-joint (No. 5 of the Fifth Progress Report, a worn joint) with 36-in. angle bars and 105-lb. N.Y.C. rail was tested on a span of 74 in. with two loads of 15,000 lb. each, applied at 16 in. from the supports, thus developing a moment of 240,000 in.-lb. throughout the middle 42 in. of the span. A Penn. L-3 rail-joint (No. 1 of this report) with 38½-in. angle bars and 130-lb. P.S. rail was tested on a span of 48 in. with a single load of 33,300 lb. at mid-length of the rail-joint and a maximum moment at mid span of 400,000 in.-lb. Five applications of load were made with all six bolts tight, the initial tension being 15,000 lb. in the N.Y.C. rail-joint and 20,000 lb. in the Penn. L-3 rail-joint.

For the N.Y.C. rail-joint the two end bolts were then loosened and five applications of load made; this was followed with the tightening of the end bolts and the loosening of the two intermediate bolts. For the Penn. rail-joint, after the test with all bolts tight the two intermediate bolts were loosened and five applications of load made; this also was followed by tightening the intermediate bolts and loosening the end bolts and then by making five applications of load.

For the first two or three applications and releases of load after tightening bolts, initial adjustments of the angle bars occur, which may not be particularly significant. With all bolts tight on the N.Y.C. rail-joint, on the fifth application of load the bottom of the bars at their ends moved out slightly and at the middle the bottom moved inward about .002 in. Similarly on the Penn. rail-joint, on the first four applications of load the bottom of the bars at the ends moved very slightly outward at top and bottom, and at mid-length the bottom moved inward a total distance about .004 in. and the top moved very little; on the fifth application there was only slight movement at ends and at middle at the top, but the bottom at middle moved inward .002 in. These lateral movements for a joint with tight bolts are similar to those that have generally been found in the tests with angle bar joints and tight bolts.

With loosened end bolts on the N.Y.C. rail-joint, on the first application of load the ends of the bars moved outward, about .005 in. at their bottoms; at mid-length the bottom of the bar moved inward about .007 in.—not returning fully to the initial position upon release of load. No measurements were made at the top of the bars in these tests of the N.Y.C. rail-joint. Some further adjustments occurred during the following three loadings. On the fifth application of load the ends of the bars moved outward from .001 to .005 in. and the middle inward about .002 in. With loosened end bolts on the Penn. rail-joint, the action was much the same—during the first four applications and releases of load the bottom of the bars at their ends had moved outward, about .005 in., and the middle inward about .002 in. At the same time the top of the bar at the ends had moved slightly outward and the middle of the bars slightly inward. On the fifth application of load, there was but little movement at the ends of the bars. At mid-length the top did not move laterally but the bottom moved inward .001 to .002 in.

With the end bolts tight and the intermediate bolts loosened on the N.Y.C. rail-joint and measurements made on the bottom of the bar only, on first application of load the ends of the bars moved out only slightly, returned nearly to initial position on release of load, moved about the same amount on the fifth application of load, and returned nearly to the initial position; at the middle, on the first application of load the bottom moved inward about .005 in. and went further on more applications of load, finally failing to return to initial position by about .006 in. Little change in position was noted near the intermediate bolts in the applications and releases of load. With end bolts tight and intermediate bolts loosened on the Penn. rail-joint, the adjustment on first application of load included a slight movement outward at the top and bottom of the bars near the intermediate bolts, and the bars did not return to initial position on release of load. On the fifth application of load the only lateral movement was about .002 in. inward at bottom at mid-length. The bottom of the bars at mid-length moved but slightly outward on release of the tension in the intermediate bolts, but on application of load it moved inward as usual.

The vertical movement between rail and bar at middle and ends of bars and at points between was measured in the test of the Penn. rail-joint. Little difference was found in this vertical movement between the three conditions of all bolts tight, end

bolts loosened, and end bolts tightened and intermediate bolts loosened. It should be noted in this connection that the joints had well-fitting bars and that the inner bolts were tight in all cases.

The magnitude of the stresses observed at mid-section and the distribution of the moments for the various sections along the length of the bars were almost the same for the three conditions of bolt tension in the test of the N.Y.C. rail-joint and also in that of the Penn. rail-joint. For the N.Y.C. rail-joint there was little difference in the deflection of the joint bars themselves. For the Penn. rail-joint the deflection of the joint in the span of 48 in. differed little for the three conditions of bolt tension. The differences in restraint of the bars by reasons of all bolts tight or end bolts or intermediate bolts loosened was not large in either joint. The inclination of the neutral axis at the mid-section and the sections within the middle half of the length of the bars did not differ greatly for the three conditions. It should be kept in mind, however, that either the end or the intermediate bolts retained high tension in every test.

Comparison may be made with tests on the same two joints tested at a bolt tension of 2,000 lb. In general the stresses at mid-section were the same as found with the tests just discussed. The moment developed at mid-section of the joint was not changed. The distributions of moments along the length of the bar with the 2,000-lb. bolt tension do not differ greatly in the case of the N.Y.C. rail-joint, but in the Penn. rail-joint the moment distribution diagram is less peaked, indicating that the reactions applied to the bars are located further from mid-length. Deflection of rail-joints under load was not measured in the tests of the N.Y.C. rail-joint. For the Penn. rail-joint the deflection at middle of the span of 48 in. increased from .053 in. for tight bolts to .071 in. with 2,000 lb. bolt tension, owing no doubt in part to the increased vertical and lateral movements between rail and bars observed in the test. These results are similar to the results of tests heretofore reported.

Altogether, these tests may be taken to mean that a loosening of one bolt at one or both halves of a 6-bolt joint does not markedly affect the stresses, vertical movements, and deflections of the joint (though the lateral movement at the end of the bar becomes greater with the end bolt loosened), but that a general low bolt tension will decrease the effectiveness of the joint in various ways. It is evident that an advantage of using six bolts lies in the retention of satisfactory conditions to a greater degree when a bolt in one or both halves has become loose.

10. **The Lateral Springing of the Joint Bars Due to the Application of Bolt Tension and Vertical Loads.**—In applying a given amount of bolt tension it has frequently been observed that the amount of movement of the nut was far greater than any stretch or deformation that could take place in the bolt and threads, especially in the tests where springless washers were used. It seemed logical that the additional spring action must be in the bars. Since elasticity of this nature is desirable in maintaining bolt tension under the wearing and "wedging in" effects of service, tests were made in an effort to find the nature and amount of this springlike movement. Vertical loads were also applied to the rail-joint during these tests to further simulate service conditions.

In considering the results of these tests, it may be well to have in mind in a preliminary way some of the elements affecting the rotation of the nut in wrenching up the bolts. Aside from the frictional resistances to rotational movement the principal resistances to the turning of the nuts may be expected to include (1) stretch of bolts;

(2) distortion of threads and also of nut and bolt head; (3) general inward movement of bar to what may be called its operating initial position, including the overcoming of roughnesses of surfaces; (4) distortion of the vertical section of the bar and the rail due to pressure of bolts and obliquity and eccentricity of rail bearing pressures; (5) local bending of bar longitudinally between points of bearing and of application of bolt tension; (6) general bending of bar along its length in one or many curves due to variations in position of points of contact between rail and bar by reason of variations in fit, camber, lack of straightness longitudinally and vertically, etc.; (7) a twisting movement of the bar because of variations similar to those mentioned in (6). Number (6) is

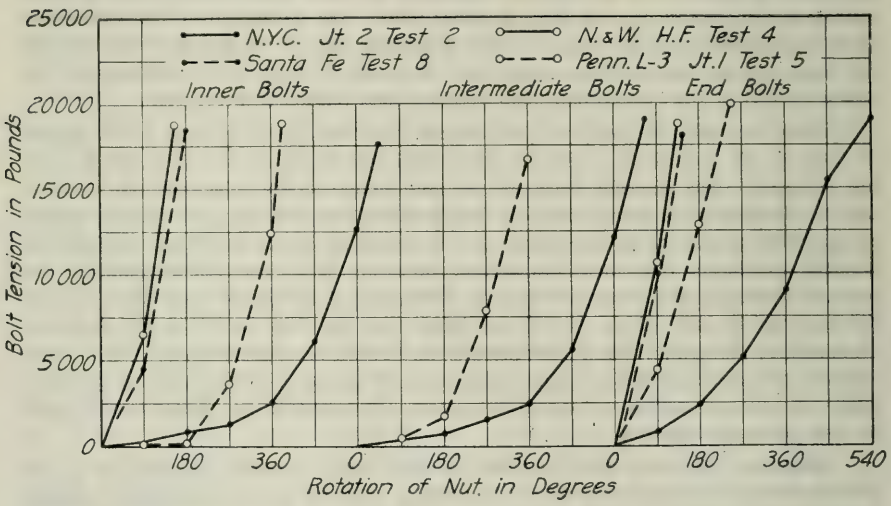


Fig. 27.—Rotation of Nut and Corresponding Bolt Tension for Four Forms of Joint Bars.

probably generally the most productive element in causing lateral spring in heavy joint bars. Of the seven elements, the first two may be considered to produce elastic resistances within the limits of the tests reported. The total stretch of each bolt may be thought of as being roughly .005 in. for a 1-in. bolt having a tension of 20,000 lb. The corresponding movement of the head and nut affects the two bars, probably usually in nearly equal parts, making about .002 in. elastic travel available to each bar from this source. Element (3) may be considered to be inelastic in effect, though the bars frequently became entirely free from the rail upon release of bolt tension. For these tests, elements (4), (5), (6) and (7) may be considered as mainly elastic.

In the first tests (Fig. 27) observations were made on only the rotation of the nut and the corresponding bolt tension when the nuts were wrenched up and loads of 33,300 lb. had been applied five times. The extensometer bolts described on page 114 of the Fifth Progress Report and already illustrated in Fig. 5 were used; these extensometer bolts give a direct indication of the bolt tension. As in other tests, the load was applied at the middle of a span of 48 in. Fig. 27 gives the average results of the observed bolt

tension corresponding to the rotation of the nut in tightening the bolts. Preliminary to these observations, a bolt tension of 20,000 lb. had been applied, the joint loaded five times with a load that developed a bending moment of 400,000 in.-lb. at mid-length (load of 33,300 lb.), and the bolt tension was then released to zero and the nuts turned up snugly. The nuts were then turned by increments of a quarter turn and the amount of the bolt tension recorded up to the tensions shown in the diagram. The diagram includes results of test 2 on N.Y.C. No. 2 rail-joint for 127-lb. rail, test 5 on Penn. L-3 rail-joint for 130-lb. P.S. rail, test 4 on the Norfolk & Western Head Free Continuous rail-joint for 130-lb. P.S. rail, and test 8 for the Santa Fe symmetrical rail-joint for 130-lb. R.E. rail. The first two rail-joints had long bars, 38 and 38½ in., and the last two short bars, 24 and 26 in. long. It should be borne in mind that in these tests springless washers were placed under the nuts.

It will be noted in Fig. 27 that the first part of the rotation of the nut produces little tension in the bolts. To develop a tension of 3,000 to 5,000 lb. requires a rotation of, say, ⅛ to ¼ turn with the Santa Fe and N. & W. joints, ¼ to ⅜ turns for the Penn. L-3 joint, and ¾ to 1¼ turns for the N.Y.C. joint. To develop a tension of 20,000 lb. requires a rotation of ⅜ to ½ turn for Santa Fe and N. & W. joint, ¾ to 1⅛ turns for Penn. L-3, and 1½ to 1¾ turns for N.Y.C. joint. An increase in tension from 5,000 to 20,000 lb. requires a rotation of about ¼, ⅜, and ½ turns, respectively.

The values given are not entirely definite and only one joint of a kind was tested, but the results may be taken as indications of the movement of bars relative to the stretch of the bolts. As a half turn of the nut corresponds to a movement of about .06 in., the half turn obtained in increasing the bolt tension from 5,000 to 20,000 lb. in the case of the N.Y.C. joint gives a movement about 15 times the increase in stretch of the bolt. In considering the availability of the elastic spring of the bar for readjusting the position of the bar in overcoming wear, it should be borne in mind that for even wear only half of the total movement can be considered to apply to one bar. It is apparent that the movement of the bars through the first part of the wrenching of the nut has little value in maintaining desirable bolt tension in the joint in service and that the movement beyond a minimum tension of, say, 5,000 lb. is the portion having real significance in this respect. It is important also to know what part of the movement through this range may be considered to be elastic and to have "follow up" qualities in order to make it useful in holding the bars in their proper place in the joint.

Tests in greater detail were made with the Penn. L-3 bars (Penn. joint No. 1) in test 7. As the nuts were wrenched up by increments, observations were made of the bolt tension up to 20,000 lb., and the corresponding lateral movements of the joint bars with respect to the rail were also observed. The joint was loaded with a load of 33,300 lb. five times for each change in position of the nuts, and the bolt tension was observed at each position before and after loading. The lateral movements of the top and bottom of the bars at ten points in the length were measured for each bolt tension before and after the application of the five loadings but not while under load. After the loadings had been made at the 20,000-lb. bolt tensions, the nuts were unwrenched by increments and as before the same load was applied five times at each wrenching. Lateral movements of the bars were also measured as before. At zero tension the nuts had failed to return to the original position by about 100° to 200°. In all the joint had been loaded about 55 times during the tests.

The bolt tension corresponding to a given position of the nut is given in Fig. 28 and a summarized (average) value in Fig. 29 for the observed bolt tension after apply-

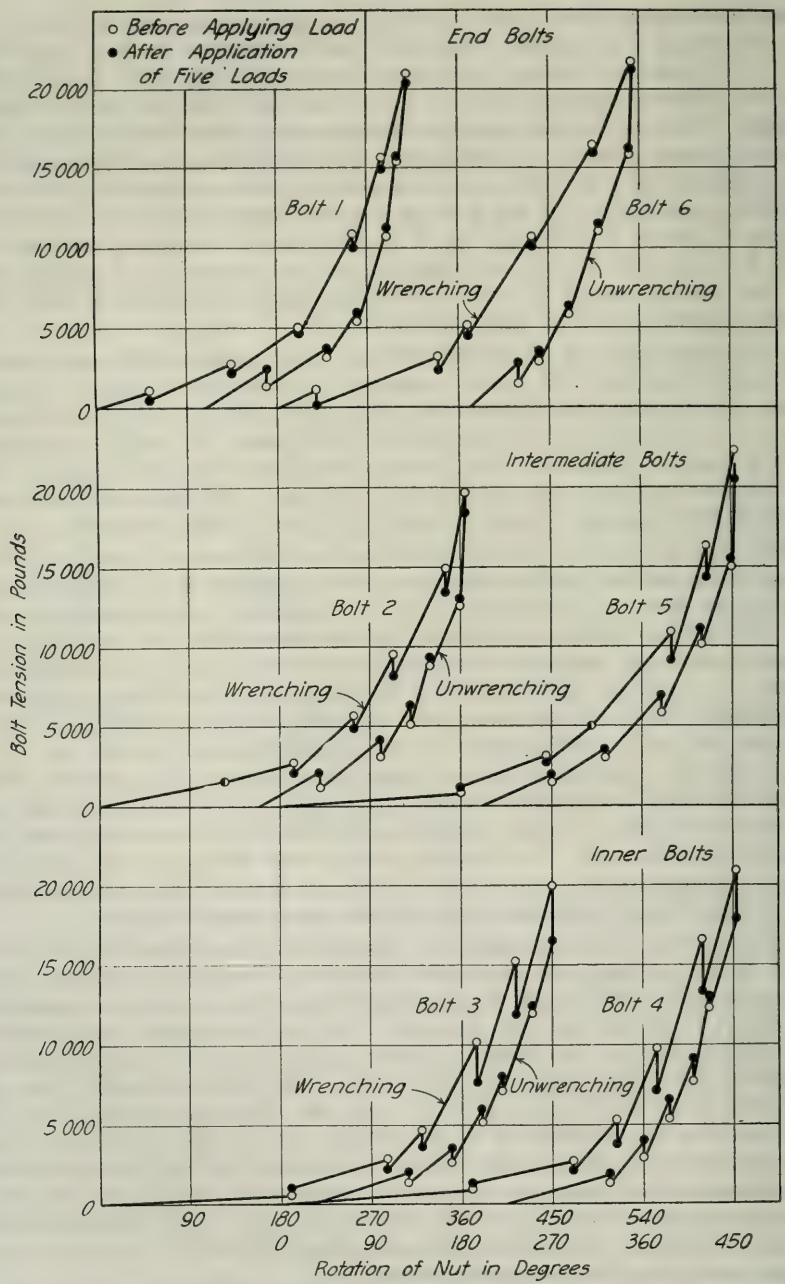


Fig. 28.—Rotation of Nut and Bolt Tension Developed before and after Application of Five Loads—Wrenching and Unwrenching—Penn. 38½-in. Angle Bars for 130-lb. Rail.

ing five loads, both for wrenching and unwrenching. In wrenching up, the end bolts took about ½ turn to reach a tension of 5,000 lb., the intermediate bolts ¾ turn, and the inner bolts ⅞ turn. For the change from 5,000 to 20,000-lb. tension each bolt required about ⅓ turn, corresponding to a movement of the nut of about .04 in. It will be noted that as the bolt tension is increased the movement of the nut (and likewise of course the movement of the bars toward the rail) becomes smaller. Evidently higher bolt tensions will give smaller and still smaller increases in the movement of the bars and in the amount of springing. It will be noted that for each position of the nut the application and release of the five loads caused the bolt tension in the unloaded joint to fall off, say, 1,000 to 5,000 lb., altogether, though the five applications each time seemed to have nearly exhausted the effect of repetition, indicating that the bars had been forced nearly into final position.

With unwrenching, the descending curves in Fig. 29 are similar to the ascending ones but more steep. In other words, the springing back movement is somewhat less or a part is not immediately available. To reduce the tension from 20,000 to 15,000 lb. involves a rotation of only 1/36 turn—a large decrease in tension for a small change in position of nut. In pulling the bar inward during wrenching up, roughnesses have to be overcome and wedging or holding occurs at various points, and these conditions require force to overcome the resistances set up but when overcome part of the spring action becomes available to maintain bolt tension. This is evidenced by the increase in bolt tension observed upon repetition of loading during the unwrenching. It is apparent that

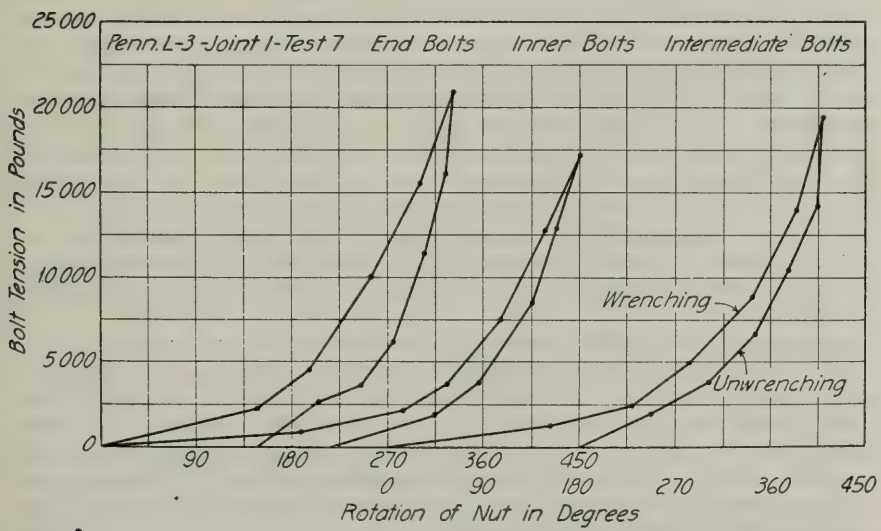


Fig. 29.—Rotation of Nut and Corresponding Bolt Tension after Five Applications of Load—Summarized Values for Wrenching and Unwrenching—Penn. 38½-in. Angle Bars for 130-lb. Rail.

the curve of available spring movement would lie between the ascending and the descending curves. In Fig. 29 the curves of both the ascending and the descending wrenchings have been drawn through the positions given by the last of the repetitive loadings. The

spring movement in unwrenching shows that elastic springing will be available in holding the bar in place or in moving it toward the rail when the bar wears in service in track.

In Fig. 30 are plotted the relative lateral positions assumed by eight points along the top of the two bars and ten points along the bottom of the bars as the bolt tensions were increased and decreased and loads applied, all taken with respect to the position of the bar before five loads had been applied for a bolt tension of 3,000 lb. in the test just described—the movement of the bars earlier in the test thus being considered a preliminary action in bringing the bars into what may be considered an initial position. The left side of the figure reading down gives positions for increasing bolt tensions (wrenching up) and the right side reading up those for decreasing bolt tensions (unwrenching). The positions shown are those taken after five loads had been applied, except that in the case of 20,000-lb. bolt tension the position both before and after the loadings is plotted. For a given bolt tension the position in wrenching up and in unwrenching may easily be compared.

It will be noted that the bolt tension of 5,000 lb. had drawn the bars inward toward the rail but that little lengthwise bending of the bar has occurred. The measurements before and after application of loads indicate that in the loadings the bars had been drawn somewhat closer to the rail. The position at 10,000-lb. bolt tension shows that the bars have been drawn still closer to the rail, though the total lateral movement of the top of the bar at mid-length is only .002 in. The bending of the bars through their length is apparent. The curvature along the bottom of the bar is a single curve convex toward the rail at mid-length of bar. The curvature along the top of the bar is concave toward the rail at mid-length and convex at the quarter points—a combination of three curves. For the tension of 15,000 lb. the bars have been drawn still nearer the rail except that little or no change has been made at the top of the bar at mid-length. The distinctive curvature along the top and bottom lines of the bars is more marked. The general inward movement of the bar along the bottom is considerably greater than that along the top. At 20,000-lb. tension the changes have continued. With the application of loads the bottom of the bars have been drawn inward still further. The top of the bar at mid-length, however, has changed position but slightly from that taken at the bolt tension of 5,000 lb. The total inward movement of the bottom of each bar between bolt tensions of 3,000 and 20,000 lb. is approximately .020 in. at mid-length and .016 in. at quarter points; the inward movement of the top of each bar at quarter points is .012 in. The inward movement of the ends of each bar at both top and bottom averages about .007 in.

In unwrenching, at 15,000-lb. tension the bars have not fully recovered the position held at the same tension for the wrenching up, though the difference is not great. Further progress in recovery is shown with the bolt tension of 10,000 lb. At 5,000-lb. bolt tension the bars have straightened nearly to their original lines. However, they remain generally .002 to .008 in. closer to the rail along their length, a change that may be due to inelastic action and to breaking down of roughnesses of surfaces. The total amount of the net movement of an elastic springing character for two bars may be taken to be .012 to .016 in., or .006 to .008 in. for each bar.

In the same test of the Penn. L-3 joint stresses were measured at three gage lines at mid-section of the bars to find the stress developed by the bolt tension. For a bolt tension of 20,000 lb. and no load applied, the tensile stresses developed at the top of the bar (points 1 and 2) were 5,000 and 11,000 lb. per sq. in., and at the bottom of the bar (point 8) tensile stresses of 4,000 lb. per sq. in.

The tests described indicate that considerable elastic springing action is brought into play in joint bars by the tension in the bolts, which even for the thick, heavy bars used

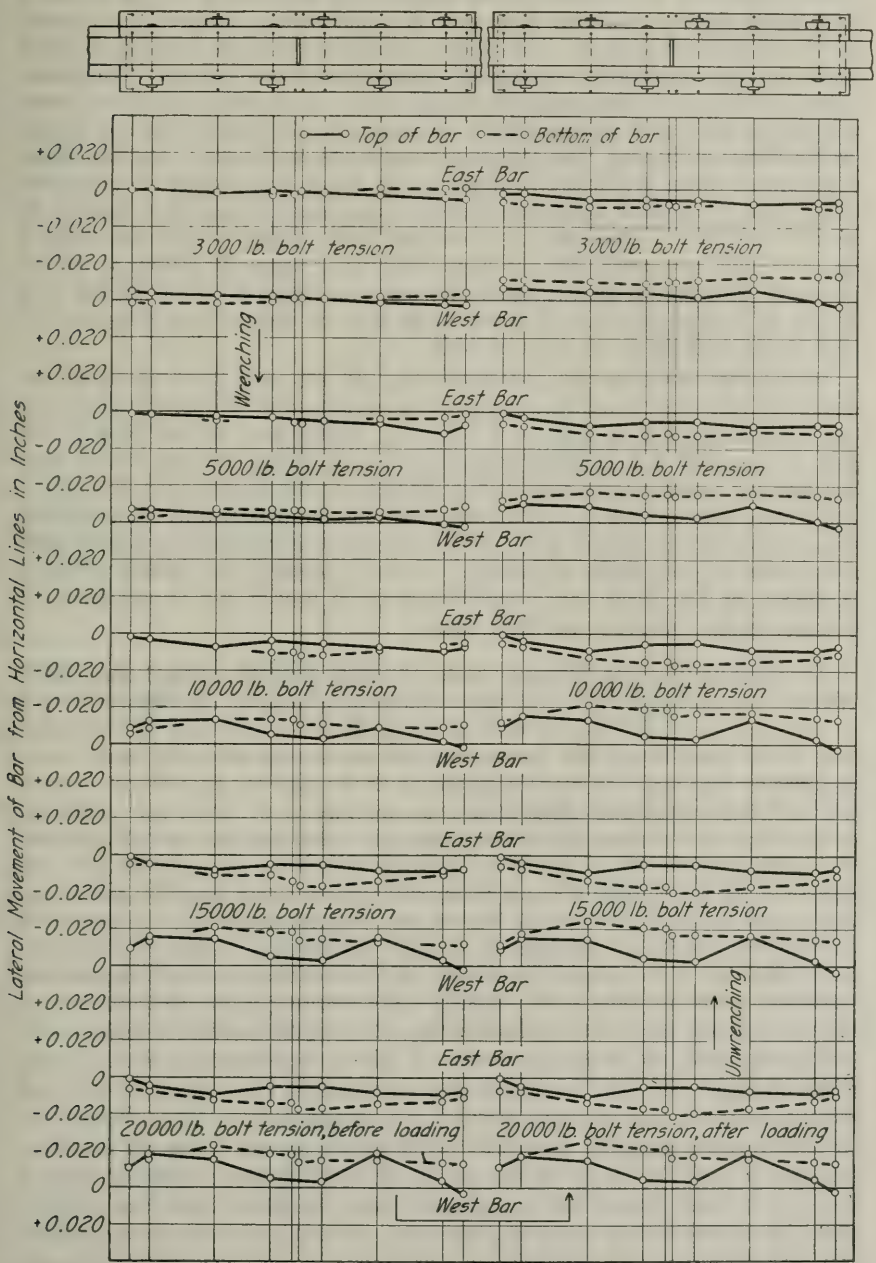


Fig. 30.—Lateral Movements of Bars Due to Bolt Tension and Loadings Relative to Their Position for a Bolt Tension of 3,000 lb.

in the tests must be useful in maintaining tension in the bolts and in holding the bar in place against the rail even after some wear of fishing surfaces occurs. It is apparent that the springing action of bars and rail is a principal source of the maintenance of bolt tension in rail-joints subjected to repeated movements and wear in track. The bending of the bars along their length into one or more curves shows where part of the energy is stored, but other portions may exist in the bending of the vertical section of the bar and the flanges of the rail. The differences found in the magnitudes of the bolt tension at the same position of the bolt in wrenching up and in unwrenching are not wholly inelastic, and the available and usable springing action must lie somewhere between the two curves of Fig. 29. The triple curve along the length of the top of the bar shown in Fig. 30 is quite in contrast with the single curve found along the bottom of the bar. The elastic movement of the two bars at the bolt holes, found to be .012 to .016 in. in this test, is three to four times the stretch in the bolt, the changes being measured from a bolt tension of 5,000 lb. to one of 20,000 lb.

The amount of the springing action naturally will vary with the design of the rail-joint. The four joints tested gave rotation of nuts required to increase the bolt tension from 5,000 to 20,000 lb. in ratios of 1, 1½, and 2 for the Santa Fe and N. & W., the Penn. L-3, and the N.Y.C. joints, respectively, but the values obtained from a single joint may not be taken to be generally representative of the characteristics of a type of joint. More tests would be needed to determine fully the characteristics of a rail-joint. It is apparent that the amount of springlike travel of the bars depends in varying degree upon number of bolts, shape and thickness of section, length of bar, camber or lack of straightness, fit, and peculiarities of individual bars. It may be well to note again that no spring washers were used with these joints.

11. **Distribution of Stresses over Vertical Section at and near Mid-Length.**—An important use of the stresses observed in tests of rail-joints in track is the determination of the resisting moment developed in the joint bars by the applied load. In the calculation of this moment the observed stress at two points in the section has generally been used, one near the bottom of the bar and one near its top. For the outer bar stresses have been observed at two gage lines on the upper part of the bar, one near the very top (gage line *A*, Fig. 3) and one farther out from the rail and somewhat lower (gage line *B*), as well as at a gage line toward the bottom of the bar. The presence of the wheel flange prevents measurement at the higher gage line, and so gage line *A* is not usable on the inner bar in tests with locomotives and cars. As reported in the Fifth Progress Report, the stress in the outer gage line (at or near *B*) is relatively smaller than that at the top gage line and its use in the calculations gives a moment that is generally smaller than the applied moment. The deficiency in this observed stress, as compared with the value which would give the actual applied moment, is thought to be due to such matters as the bearing pressure of the rail concentrated on the top fishing surface of the bar at or near the section under consideration, which affects the magnitude of the strain at this point, and also probably to local lateral and vertical bending of the bar at this section caused by eccentricity of the loading applied by the rail to the bar and other factors. To obtain information on the characteristics of different forms of joint bars in these respects and to determine factors similar to those that might be applied to the data of field tests in the calculation of bending moments developed in the joint bars, laboratory tests were made on four Penn. L-3 joints, one Penn. symmetrical joint, and two Santa Fe symmetrical joints. Four of the Pennsylvania joints had been taken from the Pennsylvania Railroad track tested at Claymont. The Santa Fe rail-

joints were of the same section as those in the C. & O. Railway track at Ashland, Kentucky, but the bars were short ones.

The tests generally were made with a single load at the middle of a 48-in. span, but as check tests several tests were made with two-point loading that gave a uniform moment over the middle 36 or 42 in. with the same magnitude of moment as that developed at mid-span in the other tests. Eight to twelve gage lines or more (4-in. or 2-in. or both) were placed at the mid-section of the bars. Generally bolt tensions of both 2,000 and 20,000 lb. were used in the tests. For both forms of loading, the maximum moment developed was 400,000 in.-lb. in two bars at mid-length.

The tests gave general results similar to those in the tests already described. The deflections were somewhat larger for the low bolt tension than for the higher but the stress and its distribution over mid-section were nearly identical for both bolt tensions. The results for the two loads applied were approximately proportional to the moments.

Fig. 31 gives at the upper left for Penn. L-3 joint No. 1 (new or unused joint) the stresses observed over the mid-section plotted with respect to a horizontal gravity axis for an applied moment of 400,000 in.-lb. (two-point loading, average for the two bars). It will be noted that the stresses are generally not proportional to the distances from the horizontal axis, as is indicated by the deviation of the stress curve from the theoretical line. Attention may be called to the difference between the relative magnitudes at the two gage lines near the top of the bar (points 1 and 2); the stress at point 1 is particularly large. The general S-form of the curve is similar to that noted in the Fifth Progress Report. Even when plotted with reference to a favorably inclined axis the stress line was found not to be straight and the stress curve varied considerably from a straight line; it was found that the most favorable position of the axis for reducing the effect of dissymmetry is an inclination of about 20° with the horizontal. Of course, the change of inclination of axis does not entirely eliminate the S-shape.

A contrast to this stress curve is seen in the stress curve shown at the upper right in Fig. 31, which is the plot of the results of the test of the same joint when the rail ends were separated by a gap of 14¼ in. and bolts were placed in the end holes of the bars only (high bolt tension used) and a two-point loading applied as in the other test. It is seen that the stress curve is fairly straight and differs little from the calculated stress line based on the usual stress analysis; if plotted with reference to an axis having an inclination of 9° the agreement of the observed and the calculated values is remarkably close. The separation of the two rails has left the mid-section free from the application of concentrated bearing pressure by the rail. These differences and whatever restraint is applied to the bars by the rails has produced a resulting straight-line distribution of stress over the vertical section. It is plain that for the regular set-up of the joint the lack of proportionality between stresses at different gage lines is something that must be taken into account in making calculation of resisting moments developed in the joint bars.

At the lower part of Fig. 31 are given the stress distribution curves at mid-section for bars from joints 11 and 5 of the test track at Claymont. The distribution does not differ greatly from that of joint 1. The curves have a marked S-shape and this shape is found to be retained even when the stresses are plotted with reference to an inclined axis. An axis inclined about 20° straightens out much of the jaggedness, but an S-form remains.

In the upper left of Fig. 32 the stress distribution at mid-section is given for the Penn. symmetrical bars taken from joint 2 of the track at Claymont. The value of the

stresses at the two top gage lines are close to the analytical ones but that at the lowest gage line is slightly smaller. As would be expected, the S-form is more marked in the top portion than in the lower part. The stress curve is free from the jaggedness found in unsymmetrical bars.

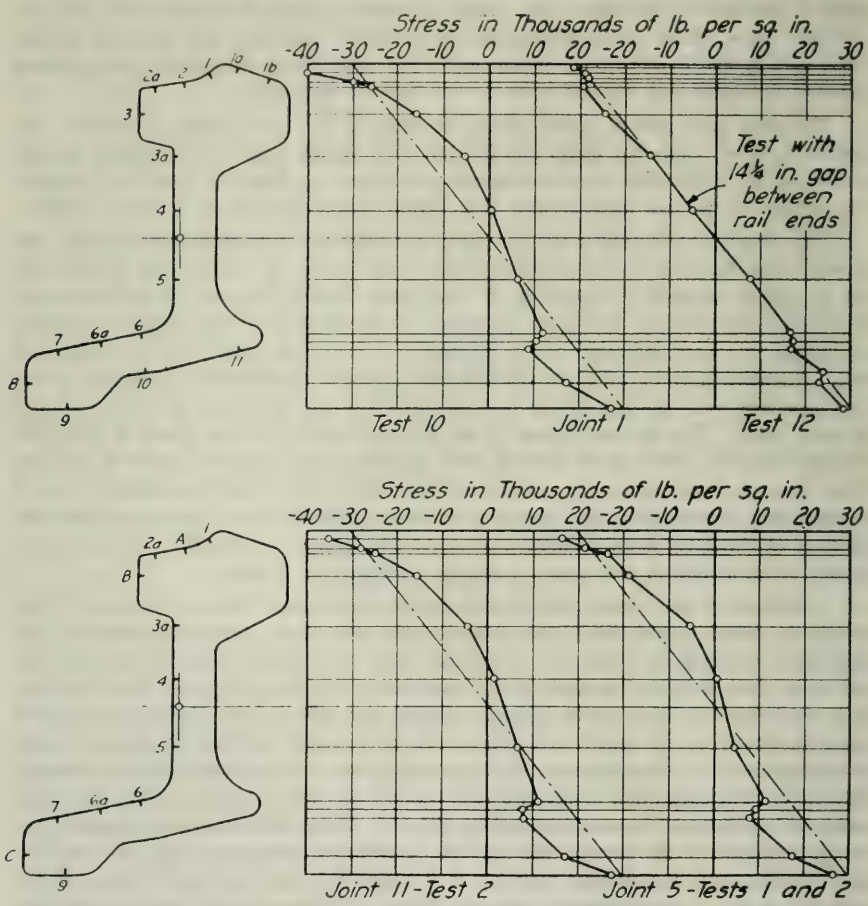


Fig. 31.—Observed Stresses at Mid-Section for 38½-in. Penn. L-3 Joint Bars for 130-lb. Rail—Also Test with Rail Ends Separated to Make a Gap of 14¼ in.

In the lower left of Fig. 32 the stress distribution at mid-section is given for the Santa Fe symmetrical joint No. 1. The values for joint 2 are almost identical with those of joint 1. Here again the same general form of curve exists. The deviation from the theoretical stress line is more in the upper part where the main effect of bearing pressure may be expected to be, and smaller in the lower part. The application of a negative load having the same magnitude as the positive (see lower of the figure) gives

a similar stress curve but oppositely disposed. The rail bearing pressure near mid-length of bar is, of course, on the bottom of the bar and the greater divergence from straight line relation is in the lower portion of the section as is to be expected.

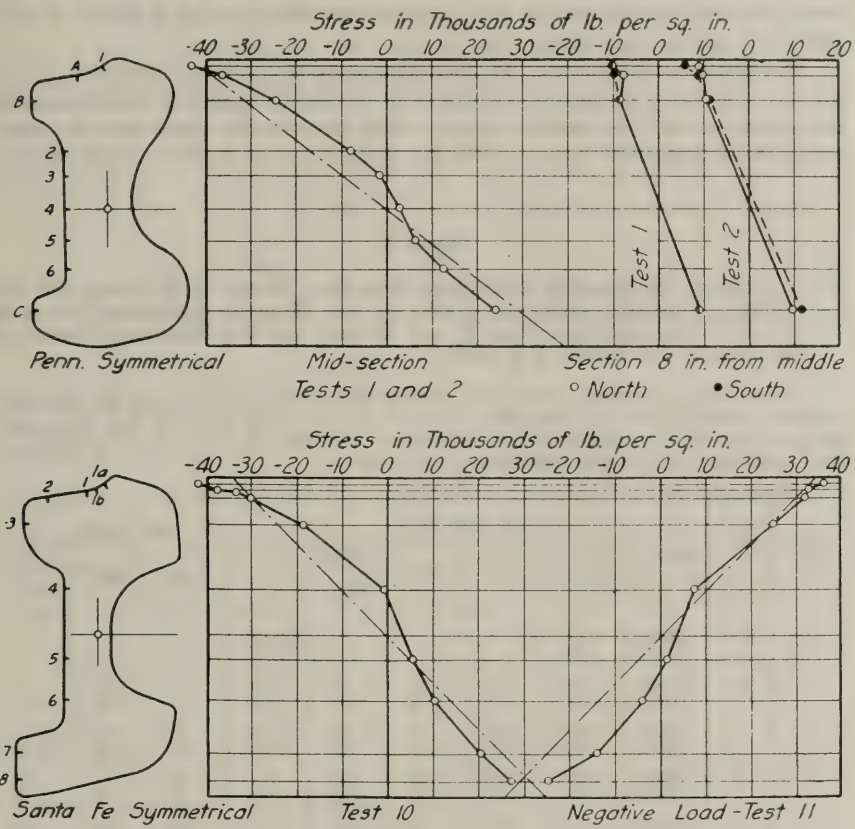


Fig. 32.—Observed Stresses at Mid-Section for 38½-in. Penn. Symmetrical Joint Bars for 130-lb. P.S. Rail and at Sections 8 in. Away, and at Mid-Section for 26-in. Santa Fe Symmetrical Joint Bars for 130-lb. R.E. Rail for Positive Load and Negative Load.

The gage lines used in all these tests naturally were placed on the surface of the bar away from the rail. It is apparent that the stresses may be different on the opposite surfaces and also at points within the bar. The purpose of these tests, however, was to throw light on the relation between the stresses at places where gage lines would be accessible in the track and to make a comparison of the moments calculated therefrom with the magnitude of the moment applied to the bars.

The data of such tests as those just described may be utilized to find conversion ratios by which the moment calculated from the observed stresses may be converted or corrected to agree more closely with the value of the moment applied to the joint. In Tables 3, 4 and 5 values are given of the ratios between the moments calculated from

the stresses observed at two given gage lines (such as gage line *A* and gage line *C*) and the applied moment. The calculated moments were computed by equation (67), which is given in Article 4 "The Function and Action of the Rail-Joint," using the observed stresses and the coordinates for the two gage lines used. A column is also given for the ratio of the moment obtained by the use of two gage lines (such as *A* and *C*) to that obtained by the use of *B* and *C*.

The location of the gage lines on the section of the bar is shown in Fig. 31 and 32. In Table 3 joint 1 is the joint that was used in the general laboratory tests reported in the previous articles. In joints 11, 5, and 1 (lat. def.) the bars taken from the joints having the same number in the track of the Pennsylvania Railroad at Claymont were

TABLE 3

Ratio between the Moment Calculated from Two Observed Stresses and the Applied Moment; Also the Ratio of the Moment Calculated from A and C to the Moment from B and C—All for Mid-Section—Penn. L-3 Rail-Joints for 130-lb. P.S. Rail

Test 11 and 12 of joint 1 and test 1 of joint 11 are two-point loading; all others are one-point loading. The first two lines for test 3 of joint 5 use values of 4-in. gage readings taken on plugs projecting ¼ in. and likewise the first two lines of test 4 values on plugs projecting ½ in. Bolt tensions are 20,000 lb.

Joint No.	Test No.	Load	2-in. Gage Lines				4-in. Gage Lines			
			1&C	A&C	B&C	A&C / B&C	1&C	A&C	B&C	A&C / B&C
1	11	25000	1.17				1.01			
		50000	1.18				1.02			
1*	12	25000	.98	.97	.97	1.00	1.03		1.00	
		50000	.97	.99	1.00	.99	.98		1.00	
11	1	25000	1.09	.92	.79	1.16	1.04	.89	.76	1.17
		50000	1.13	.98	.80	1.22	1.07	.93	.79	1.18
11	2	16800	1.09	.91	.60	1.52	.96	.86	.76	1.13
		33400	1.07	.88	.66	1.33	.97	.85	.72	1.18
5	1	16800	1.04	.93	.80	1.16	1.01	.84	.70	1.20
		33400	1.04	.92	.76	1.21	.96	.90	.73	1.23
5	2	16800	1.03	.83	.70	1.18	.91	.83	.67	1.24
		33400	1.04	.89	.70	1.27	.96	.88	.73	1.20
5	3	33300	1.07	.92	.70	1.31		.93	.71	1.31
		33300	1.04	.92	.72	1.28		.97	.71	1.37
		33300					.97	.88	.74	1.19
		33300	1.08	.91	.73	1.25	.97	.88	.74	1.19
5	4	33300	1.04	.91	.71	1.28		.97	.68	1.43
		33300	1.06	.93	.73	1.27		.97	.69	1.41
		33300					.97	.89	.74	1.20
		33300	1.05	.91	.71	1.28	.96	.88	.74	1.19
1 (lat. def.)	1	16800	.97	.90	.86	1.05	.98	.91	.80	1.14
		33400	1.01	.95	.80	1.19	1.00	.95	.78	1.22
1 (lat. def.)	2	16800	.94	.92	.79	1.16	1.00	.92	.79	1.16
		33400	1.01	.94	.76	1.24	1.02	.94	.77	1.22

*Results for tests with rail ends separated 14¼ in.

TABLE 4

Ratio between the Moment Calculated from Two Observed Stresses and the Applied Moment; Also the Ratio of the Moment Calculated from A and C to the Moment from B and C—All for Mid-Section—Penn. Symmetrical Rail-Joints for 130-lb. P.S. Rail

Tests are single-point loading. The first two lines for the 4-in. gage values in both test 3 and test 4 were taken on plugs projecting ¼ in. Test 3 was made with low bolt tension; test 4 with high bolt tension.

Joint No.	Test No.	Load	2-in. Gage Lines				4-in. Gage Lines			
			1&C	A&C	B&C	A&C / B&C	1&C	A&C	B&C	A&C / B&C
2	3	33300	1.04	.97	.81	1.20		.96	.83	1.16
		33300	1.02	.93	.81	1.15		.94	.80	1.17
		33300					.96	.91	.80	1.14
		33300	1.03	.93	.81	1.15	.97	.92	.81	1.14
2	4	33300	1.03	.92	.80	1.15		.95	.81	1.17
		33300	1.03	.92	.76	1.21		.93	.78	1.19
		33300					.93	.90	.79	1.14
		33300	1.03	.92	.76	1.21	.95	.89	.79	1.13

TABLE 5

Ratio between the Moment Calculated from Two Observed Stresses and the Applied Moment; Also the Ratio of the Moment Calculated from 2 and 8 to the Moment from 3 and 8—All for Mid-Section—Santa Fe Symmetrical Rail-Joint for 130-lb. R.E. Rail

Tests are single-point loading. Bolt tension 20,000 lb. In test 11 the applied moment is negative. The bars of joint 1 and joint 2 were new or unused bars.

Joint No.	Test No.	Load	2-in. Gage Lines				
			1a & 8	1 & 8	2 & 8	3 & 8	2 & 8 / 3 & 8
1	10	33300	1.26		.93	.80	1.16
		33300	1.25	1.03	.95	.83	1.14
		33300	1.28	1.03	.92	.81	1.14
		16700	1.21	1.04	.92	.80	1.15
		33300	1.24	1.02	.94	.81	1.16
		16700	1.29	1.01	.92	.82	1.12
		33300	1.27	1.04	.94	.82	1.15
		33300	1.26	1.04	.95	.83	1.14
		33300	1.27	1.07	.93	.82	1.13
1	11	16700	1.12	1.11	.88	.86	1.02
		33300	1.11	1.02	.91	.87	1.05
		16700	1.13	1.03	.91	.84	1.08
		33300	1.10	1.02	.96	.87	1.10
2	1	16700	1.12	.94	.81	.68	1.19
		33300	1.26	1.04	.93	.80	1.16
		16700	1.25	1.05	.85	.73	1.16
		33300	1.29	1.04	.90	.80	1.13
2	2	33300	1.32	1.07	.92	.83	1.11
		33300	1.33	1.07	.92	.81	1.14
2	3	33300	1.25	1.11	.92	.82	1.12
		33300	1.27	1.08	.93	.83	1.12

used in the laboratory tests; the bars of joint 1 (lat. def.) were deformed laterally as described in Article 7b "Penn. Rail-Joint for 130-lb. P.S. Rail." The bars of Table 4 were the pair of Pennsylvania symmetrical bars taken from joint 2 at Claymont. The Santa Fe symmetrical bars of Table 5 were the bars used in tests reported in Article 7d "Santa Fe Symmetrical Type Rail-Joint for 130-lb. R.E. Rail."

It is of interest to note that test 12 of joint 1 (a Penn. L-3 joint for 130-lb. P.S. rail), which had the rail ends separated by a gap of 14¼ in. and which shows a straight line stress distribution over mid-section in the upper right in Fig. 31 as described earlier in this article, has values of conversion ratios applicable to moment calculations that are very near to unity. (See Table 3). This is a further corroboration of the correctness of the methods and formulas used in this report for converting or correcting the moments calculated from the observed stresses to agree more closely with the value of the moment applied to or developed in the joint—a conversion necessitated by the disturbing effect on the stress at certain gage lines at the top of the bar made by the load bearing pressure of the rail near its end.

In certain tests of Tables 3 and 4 small plugs were screwed into the bar at the location of the gage points in such a way as to extend away from the surface of the bar ¼ in. or ½ in. and gage holes were drilled in their outer ends at points corresponding to the usual gage points and the gage measurements were taken for these gage lines; the purpose was to reproduce the positions of the points of measurement made in the field tests at Claymont with the Westinghouse magnetic strain gage and to furnish comparisons with measurements made at gage points at the surface of the bars.

In the several combinations of gage lines referred to in the tables, the same lower gage line is used, but different gage lines are used as the higher gage line of the combination. It will be noted that for each combination of gage lines, the ratios given in each of the three tables are fairly uniform and consistent. The ratios for the high points of the bars and 2-in. gage lines are generally greater than unity, and those for the gage lines farther from the rail and lower in position are smaller than unity. The ratios for the 2-in. gage lines are generally larger than for the 4-in. gage lines, and even for the high gage line the values given are generally somewhat greater than unity. The ratios for the upper gage line that is away from the rail (like *B* and 3) are considerably less than those for a gage line close to the top point of the bar.

The ratios in the fourth column for both 2-in. and 4-in. gage lines are all greater than unity. They show the relative discrepancies in using either one of the two positions of an upper gage line and the need of a conversion factor.

For the Penn. L-3 bars the difference between the ratios found with readings on the plugs and those on the surface of the bar vary with the gage line considered. The ratio of *A* and *C* to *B* and *C* is greater with plugs than without. For the symmetrical type of bar the corresponding values with and without plugs do not differ much.

The ratios given for the negative moment in one combination of gage lines is smaller than those for positive moment and in others it is larger or not greatly different.

Attention is called to the fact that ratios calculated from the stresses observed in the test made with the rails separated some distance (stresses shown in upper right of Fig. 31) approximate very closely to unity (see Table 3). This is equivalent to saying that the stress distribution at mid-section given in the figure is nearly a straight line.

The three tables give interesting information on the differences in calculated moments obtained with stresses observed for gage lines at different positions. It is not to be expected that the values given in the tables will be applicable directly and accurately to

finding the correct value of the moment developed in the bars of the joints in the track, for the track joints are subject to unknown lateral bending (both bending of individual bar and bending of the joint as a whole) and the position and amount of the application of bearing pressure in the track may differ for different joints, whereas in the laboratory the conditions imposed are fairly uniform in all the tests. However, the values in the tables will be found useful in interpreting tests of the rail-joints in track.

In tests of Penn. symmetrical joint (test 1 and 2) stresses were measured at two sections 8 in. each way from mid-section, which throw light on the variation in stresses in a section away from pressure bearing areas existing near mid-section. The 4-in. gage lines 1, *A*, *B* and *C* (see Fig. 32) gave stresses which are plotted at the upper right of the figure, the open circle representing the observations at 8 in. to the north of mid-section and the solid circle 8 in. to the south—the two tests being reported. Lines connecting the four points are close to the analytical stress distribution for pure flexure. Although no gage lines were used near mid-depth of section it is probable that the stress line does not deviate far from a straight-line distribution. It is evident the section is far enough away from the top bearing pressure to be unaffected by these pressures. The results are similar to those observed in the test of a rail described in the Fifth Progress Report, page 189.

The calculation of the moments developed in rail and bars at these two sections from the observed stresses shows that the sum of the moment developed in the rail and that in the two bars is about 260,000 in.-lb., which is close to the magnitude of the applied moment at these sections. Of this sum, 155,000 in.-lb. is taken by the rail and 105,000 in.-lb. by the two bars. The moment developed in the bars in these tests is about .40 of that developed at mid-section. The foregoing values were calculated from stresses at gage lines *A* and *C*. The use of stresses at *B* and *C* or at 1 and *C* would give somewhat larger values of the moment at the two sections.

12. **Deflection of Rail-Joints and Joint Bars.**—In the laboratory tests of rail-joints observations were made of vertical deflections of both joint bars and rail-joint as a whole upon the application of load. Table 6 gives some of the results. The joints have been described elsewhere. I.C. joint No. 3 (90-lb. rail) was somewhat worn. The other joints may be called well fitting, except the Santa Fe joint, which had some looseness in one half, a condition which partly accounts for the higher value of its ratio in the table. The values given are the deflections for the last of five repeated loadings (except where a first loading is indicated) and do not include any play that might be found between a negative and a positive load, except in the case of the Muller joint. The span was 48 in. and a single load was applied at the middle, except where otherwise noted; the exceptions are the Continuous joints, which had two-point loading. Under the heading "Rail-Joint" are given (a) the observed vertical deflection of the rail and rail-joint at the middle of the span used, (b) the calculated middle deflection for a full rail with the same span and loading, and (c) the ratio of (a) to (b). This ratio enables comparisons to be made in terms of the deflection of full rail. The closeness of this ratio to unity is an indication of the ability of the rail-joint to distribute load over a number of ties as compared with the action of full rail. The columns under "Joint Bars" give the middle deflection of the joint bars from end to end, whether the bar is short or long. "Top" refers to a line along the top of the bar and "Bottom" to one along the bottom. It will be noted that the deflection of the rail-joint when low bolt tension is used is considerably greater than for high bolt tension, due principally to the increase in play between rail and bars with low bolt tension. The deflection of the joint

TABLE 6

Observed Vertical Deflection of Rail-Joints and Joint Bars

The dimensional units are inches and pounds.

Name and Test No.	Load	Bolt Tension	Rail-Joint			Joint Bars			
			Observed Deflection of Joint	Calc. Rail Deflection	Ratio Observed to Calculated	East Bar		West Bar	
						Top	Bottom	Top	Bottom
I. C. No. 3									
33	20000	20000	.067	.040	1.69		.024		.023
34	20000	2000	.091	.040	2.30		.031		.031
N.Y.C. (127-lb.) No. 1									
1	25000	20000	.038	.023	1.65		.028		.027
2	25000	2000	.052	.023	2.26		.040		.040
3	33300	20000	.050	.030	1.64		.034		.034
	—13300	20000	—.022	.012	1.83		—.017		—.016
Penn. L-3 No. 1									
1	33300	20000	.055	.035	1.57	.037	.039	.039	.042
2	33300	None on 2 & 5	.051	.035	1.45	.037	.038	.039	.045
3	33300	None on 1 & 6	.052	.035	1.48	.036	.036	.037	.044
4	33300	2000	.071	.035	2.02	.046	.042	.049	.049
Penn. L-3 No. 11									
2	33300	20000	.058	.035	1.65	.041	.040	.041	.042
Penn. L-3 No. 1 (lat. def.)									
3	33300	20000	.065	.035	1.85	.044	.042	.046	.046
Penn. sym. No. 2									
1	33300	20000	.080	.035	2.28				
2	33300	4000	.087	.035	2.48				
Santa Fe No. 1									
4	33300	20000	.068	.033	2.06	.026		.026	
	—13300	20000	—.024	—.013	1.85	—.010		—.010	
N. & W. head-bearing Cont. No. 1*									
1	50000‡	15000	.175	.117	1.49	.019		.017	
	50000‡	2000	.225	.117	1.92	.021		.022	
N.&.W. head-free Cont. No. 1*									
1	50000‡	15000	.152	.098	1.55				
	50000	15000	.135	.098	1.38	.021	.007† .017	.020	.009† .017
2	50000‡	2000	.188	.098	1.92				
	50000	2000	.183	.098	1.87	.021	.009† .025	.018	.010† .020
3	50000	8000	.161	.098	1.65	.021	.010† .025	.018	.010† .022

TABLE 6—Continued

Name and Test No.	Load	Bolt Tension	Rail-Joint			Joint Bars			
			Observed Deflection of Joint	Calc. Rail Deflection	Ratio Observed to Calculated	East Bar		West Bar	
						Top	Bottom	Top	Bottom
Muller No. 1									
	25000†	20000	.119	.025	4.76				
	25000	20000	.090	.025	3.60				
	—12500‡	20000	—.219	—.013	16.8				
	—12500	20000	—.067	—.013	5.15				

*Two-point loading was used with spans of 74 in. and 68 in. for the N. & W. head-bearing and head-free joints, respectively. The two loads were applied 16 in. from the supports and produced a moment of 400,000 in.-lb. between the points of application of the load. In all other tests the load was applied at the middle of a span of 48 in.

†The upper value is for a line along the outer edge of the bottom of the reflexed flange and the lower for one along the inner edge.

‡First loading.

bars is also greater for low bolt tension than for high bolt tension. This may be due partly to the greater distance between the resultants of the reaction forces and the position of the bearing pressures when the tension is small and partly to the smaller restraint and the greater inclination of the neutral axis with low bolt tension. The differences in the deflection of the Head Free Continuous joint for lines along the top of the bar, along the outer edge of the bottom of the reflexed flange, and along the inner edge of this flange is an interesting phenomenon. It is evident that the section of the bar does not act integrally during bending. The deflections for negative load upon fifth application are nearly proportional to those for positive load except for the Muller joint. In this joint the first application of negative load gave very large deflection and there was considerable play between the position of the joint bars under positive load and that under negative load, quite in contrast with the corresponding movement of the other forms of joint. The magnitude of the deflection of the Muller joint under positive load from a position where play is overcome is much greater than for the other joints.

Although the method of supporting the joints in these laboratory tests is far from being the same as the support given by the ties in track, the form of the moment curve is not greatly different and the information here given has value in making comparisons. It should be added that for joints having play between bars and rail the deflections become very much greater.

Observations were also made on the lateral deflection in the length of the joint bar. Although the lateral deflection was small, its magnitude with reference to a chord along the bottom of the angle bar was considerably greater with low bolt tension than with high bolt tension. For the symmetrical bars, the deflection was very small with high bolt tension and larger with low bolt tension—the increase in the latter case being due to the outward movement of the bars at their ends by reason of the long distance from the end bolt to the end of the bar in this 4-bolt joint. The lateral deflections observed in the tests ranged from 0 to .012 in.

III. TESTS OF RAIL-JOINTS ON THE PENNSYLVANIA RAILROAD

13. **Purpose of Tests and Arrangements Therefor.**—All the previous tests of rail-joints for obtaining stresses and movements in the joint bars were made with static loading. It has been thought by some engineers that the action of the rail-joint under moving load at train speeds must be far different from that under static loading, that the approach of the wheel load would produce stresses and movements in the joint bars and bolts quite different from those found in static tests, and that at high speeds of the moving load stresses of much greater magnitude are developed. Accordingly, at the first opportunity arrangements were made to measure stresses in the joint bars of rail-joints in track and the tension produced in the joint bolts through the application of moving wheel loads at various speeds.

The principal obstacle in the way of making measurements of stresses in rail-joints under moving loads had been the lack of an instrument which was suitable for the purpose. The stremmatograph that had been used in measuring stresses at base of rail could not be applied to the joint bars to measure stresses at more than one gage line on a section of the bar, while gage lines at two or more points in the section of the bar are needed to obtain the data necessary for computing the bending moment developed in the joint bar. No instrument applicable to the rail-joint in track and recording the stresses developed under such conditions was available. The Westinghouse Electric and Manufacturing Company for several years had been developing an instrument for measuring stresses on pieces or parts when subjected to the action of moving loads; the records of the stresses made by the instrument are produced on photographic films through the agency of the oscillograph, which is placed in a shelter at some convenient point on the railroad right-of-way. This instrument, known as the Westinghouse magnetic strain gage, had been found to give definite and accurate records when used to measure stresses in rail at train speeds without being seriously affected by the vibrations of the rail even at the highest speeds used. In order to take advantage of this type of instrument for tests of rail-joints in track, suggestions were made to the Westinghouse Company on the form and dimensions and restrictions needed for a magnetic strain gage suited to the joint bar, and other help given. The engineers of the Westinghouse Company then designed and developed a compact form of magnetic strain gage, which with certain limitations may be attached to the joint bar at different places and gives accurate and trustworthy records of stress at high train speeds. The auxiliary equipment used with the magnetic strain gage is elaborate and expensive, but its use has proved it to be a satisfactory and reliable apparatus for measuring and recording stresses under moving loads. Before making moving load tests on rail-joints, the staff of the Committee designed and developed and calibrated special extensometer bolts to which the special magnetic strain gage could be applied for determining changes in tension in the joint bolts which might occur upon the application of a moving load at train speeds. This apparatus was found to be accurate and satisfactory and well fitted for the purpose.

During September and October, 1930, the staff of the Committee participated in tests of track of the Pennsylvania Railroad on its electrified section at Claymont, Delaware (near Wilmington), cooperating with the Pennsylvania Railroad and the Westinghouse Electric and Manufacturing Company. The tests were carried out primarily to determine the action and characteristics of certain new types of electric locomotives being built for the Pennsylvania Railroad. In these tests measurements of stresses in rail and in rail-joints under the load of moving electric and steam locomotives and cars were made up to high rates of speed, using the equipment referred to above. With the elec-

tric locomotives runs at speeds as high as 100 miles per hour were made. With a steam locomotive, speeds as high as 90 miles per hour were used. The data on the stresses developed in the rail at the various speeds and under the varied conditions of the different runs have been used by the Westinghouse Company in a study of the action of the locomotives at the high speeds.

The data on the stresses developed in rail-joints have been used as the basis for the study of rail-joints given in this chapter. Only the electric locomotive and cars were used in the tests of rail-joints. Speeds of 5, 45, and 70 miles per hour were made in the tests of rail-joints, with a few runs at 90 miles per hour. Most of the tests were conducted on rail-joints of angle bar type 38½ in. long, but angle bars of the same section 24 in. long and bars of symmetrical type 38½ in. long were used. It is well to note that the track on the test stretch is heavy, stiff, high-grade track in excellent condition and especially suited for high speed and heavy traffic.

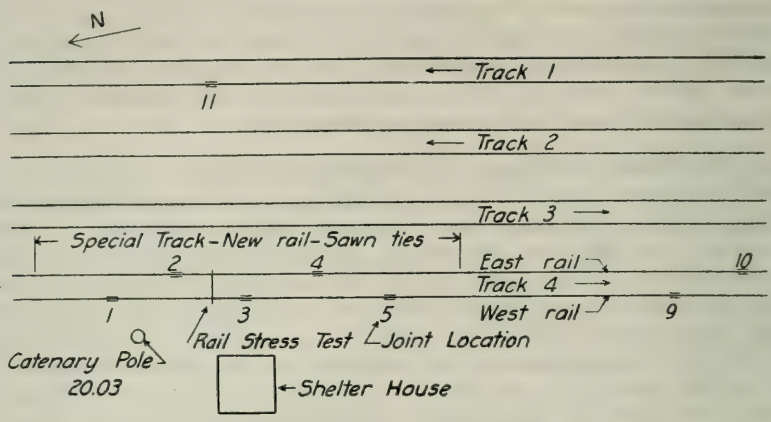
14. **The Track.**—The tests on the Pennsylvania Railroad were conducted on the southbound passenger track (No. 4) one half mile south of Claymont, Delaware, on the Maryland Division. The stretch used in the tests was the straight track at catenary pole marked 20.03 miles from Philadelphia. At the special test stretch of track new rail, new ties, and other new track materials were applied for about three rail lengths and the track brought up to standard ballast section and to new line and surface two months before the tests. The rail was 130-lb. P.S. section, 39 ft. lengths, rolled in April 1930. The ties were new sawn ties of treated oak and gum mixed, well graded as to size, 7 by 9 in. by 8 ft. 6 in., and laid 22 to the 39-ft. rail. On the prepared track the ties were well spaced, the spacing center to center of the three joint ties in almost all spacings being 19 or 20 in. The ties away from the joint were fairly well spaced, 90 per cent being spaced between 20 and 24 in. The tie-plates were heavy duty Pennsylvania standard, 7 by 14 in., with an eccentricity of ½ in. and without inclination. A driven spike in the outer and inner portions of the tie-plate attached the tie-plate to the tie independently of other spikes at the inner and outer edges of the base of rail through each plate—four driven spikes to the tie-plate. There were four Stead rail anchors to the rail length. The depth of the stone ballast below the bottom of the ties was 7 in. Beneath this for a considerable depth was a combination of stone, gravel and cinders. The entire track had been raised during the spring of 1930. The track at the test location was on a fill of 3 ft. The gage as measured during the tests was $\frac{1}{16}$ in. close. The grade was very light.

Fig. 33 shows the position of the prepared track with respect to the other three tracks and also the joint locations at which tests were made and their designation by numbers. The position of the shelter house where the auxiliary equipment was placed is also shown. Joint locations 1, 3, and 5 were in the west rail and joint locations 2 and 4 were in the east rail. At the time the new rail was laid in July these five joint locations were equipped with the Pennsylvania standard L-3 38½-in. 6-hole angle bars, 1⅛ by 6⅛-in. Pennsylvania standard bolts with Pennsylvania standard helical spring nut locks. The section of the L-3 angle bars is given in Fig. 3. The Pennsylvania symmetrical form of joint bar used in the tests is described in Article 7c, the section given in Fig. 3 and its properties in Table 2.

Joint location 9 was 60 ft. south of the special test stretch. The rail at this point was laid in 1928. The tie-plates were 7 by 10½ in. and the L-3 angle bars were 24 in. long. As the electrical leads were long enough to reach over to track No. 1 (northbound passenger) a joint was selected at joint location 11. Here there were 130-lb. P.S.

rail laid in 1929, tie-plates 7½ by 14 in. on the three joint ties and 7 by 10½-in. tie-plates elsewhere, and standard L-3 38½-in. angle bars. The track was good but not up to the conditions found on track No. 4.

The track at the special stretch was in excellent line and surface and each tie appeared to be in condition to take its share of load and the play between rail and tie bed reasonably uniform. At the highest speeds, the test locomotive had less lateral sway in passing over the special stretch than at points on either side.



The location of the joints tested is designated by numbers.

Fig. 33.—Sketch Showing Relative Position of Prepared Stretch of Test Track and Rail-Joints Tested on the Pennsylvania Railroad near Claymont, Delaware.

A few hurried measurements of track depression (under the wheels of locomotives and cars) were taken to estimate the stiffness of the track and the value of the modulus of elasticity of rail support, u. The track structure was very stiff; the incomplete data taken indicate a value of the modulus in the neighborhood of 4000 lb. per in. per in.

The measurement of rail stresses on straight track by the Westinghouse Company to determine the action of the locomotives at various speeds was made at a place between joint locations 2 and 3.

15. **The Locomotive and Cars.**—As the tests on rail-joints were made to study rail-joint characteristics rather than locomotive differences, only one locomotive was used —electric locomotive 7850 of the 0-1 type. At the time the tests were made, multiple-unit passenger cars were used for the local passenger trains and the first of the 0-1 type locomotives were being tested out in service. Steam locomotives were still operating freight trains and through passenger trains.

The 0-1 type locomotive (passenger service) has two pairs of driving wheels (diameter 72 in.) and a four-wheel truck at either end. Fig. 34 gives the nominal wheel loads and wheel spacings of the locomotive. The rigid wheel base is 10 ft., the spacing between drivers. The frame supports a single cab that extends the whole length of the locomotive. Roller bearings are provided for the motor armature bearings, the driver axles, and the axles of the trucks. The power supply was alternating current of 11,000

volts and 25 cycles from an overhead line. Two twin armature motors of 1,060 h.p. each, mounted above the driving axles, drive the wheels with gears and pinions through the medium of a link type drive. Marked improvements in the design of the single phase alternating current motors have permitted the placing close to the driving axles of motors with sufficient power to give high tractive force without the use of side rods. The speed is controlled by varying the voltage on the motors.

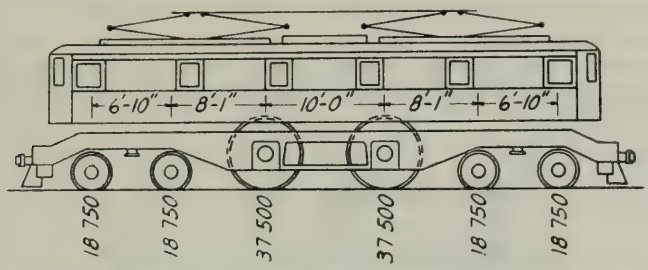


Fig. 34.—Diagram of Wheel Loads and Wheel Spacing for Pennsylvania Electric Locomotive 7850.

In test (e) the electric locomotive pulled four loaded coal cars. The first car behind the locomotive was a 50-ton car loaded to give an average load per wheel of 16,500 lb. The truck wheel spacing was 5 ft. 6 in. and the distance between interior truck wheels 16 ft. 9 in. The second car was a 70-ton inboard Timken roller bearing car with a truck wheel spacing of 5 ft. 10 in. and a distance between interior truck wheels of 26 ft. 2 in., loaded to give an average wheel load of 24,500 lb. per wheel. The third car was a 70-ton car of the same class and dimensions as the second except that it had plain bearings—the weight per wheel was 24,500 lb. The fourth car was a 90-ton four-wheel truck car (the only one of this class owned by the Company) with a truck wheel spacing of 5 ft. 8 in. and a distance of 32 ft. 4 in. between interior truck wheels—the average weight per wheel was 30,400 lb. The spacing between end wheels of two coupled cars was 6 ft. 9 in.

16. **The Magnetic Strain Gage and Its Auxiliary Equipment.**—The magnetic strain gage* developed by the Westinghouse Electric and Manufacturing Company consists of two U-shaped laminated cores (U_1 and U_2, see Fig. 35, a schematic longitudinal cross-section, in which the hatched areas represent parts that are connected to the right-hand fastening and the unhatched areas are connected to the left-hand fastening) fixed with respect to each other and wound with coils designed for the high frequency excitation used and a laminated armature (A) that moves in the gap between

* For further description of the Westinghouse magnetic strain gage and its use, see "A Magnetic Strain Gage" by J. Paul Shamberger, Proceedings, American Society for Testing Materials, Vol. 30, p. 1041 (1930), and "Rail Stresses and Locomotive Tracking Characteristics Found in Tests on the Great Northern Railway," by J. Paul Shamberger and B. F. Langer, Bulletin 339, A.R.E.A., September 1931. The original conception for this instrument is credited to J. G. Ritter. It is understood that improvements in the construction of the magnetic gages and their operation have been made since the tests were made at Claymont.

the U-cores to an amount corresponding to the strains occurring between the points of attachment of the instrument. The movement of the armature when the development of a strain changes its position with respect to the pole faces of the cores decreases the gap on one side of the armature, and increases it on the other, and thus changes the reluctances of the two magnetic paths and unbalances the voltage drops in the circuits. In the operation of the magnetic strain gage one oscillograph element (see Fig. 36 showing the lay-out of the electric circuit) is connected between the coils in such a manner that the unbalanced voltages send a current through the element that is proportional to the movement of the armature. This proportional relation will hold for a sufficiently large movement of the armature to indicate any stresses normally encountered. The oscillograph record thus gives values that are proportional to the strains.

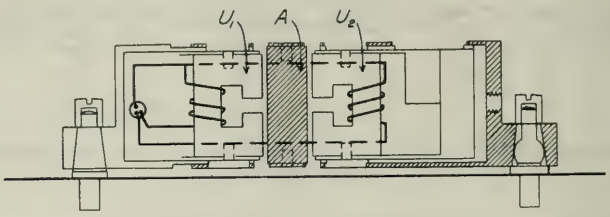


Fig. 35.—Diagrammatic Representation of Westinghouse Magnetic Strain Gage.

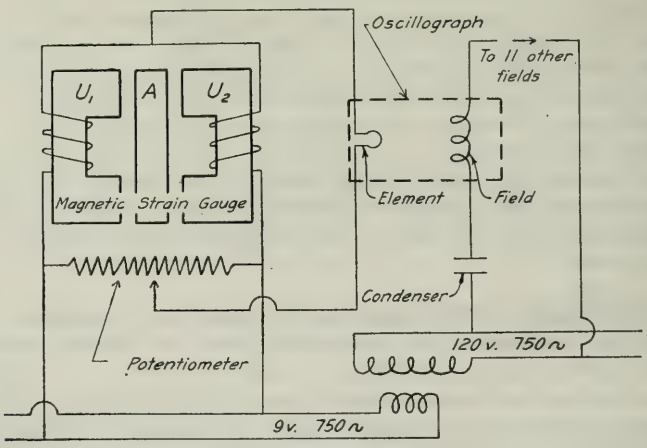


Fig. 36.—Lay-out of Electric Circuits of Magnetic Strain Gage Equipment.

As has already been mentioned, the instrument that had already been used by the Westinghouse Company in tests of rail stresses, which had an 8-in. gage length and had given excellent satisfaction, suggested the advantage to be gained by the design of a strain gage having a shape and dimensions suitable for making tests of rail-joints. The appearance of the magnetic strain gage of 4-in. gage length thus developed is illustrated in Fig. 37. Telescoping aluminum cylinders about 1 in. in diameter enclose the coils, laminated pole pieces and armature. The working parts of the strain gage are attached

to the enclosing cylinders in a manner which permits a movement of the parts sufficient to cover the strain cycles. A tolerance for variation in the distance between the studs on which the strain gage is mounted is separately provided. An outer cylindrical casing protects the instrument from weather and dust. In Fig. 37 it has been rotated to show some details. For use in mounting the strain gage, two No. 19 holes are drilled about ¼ in. deep and 10-32 threads tapped in the joint bar at the position selected, and studs screwed into the holes. These studs have spherical surfaces at the contact areas to minimize any jamming effects of small misalignments of the studs.

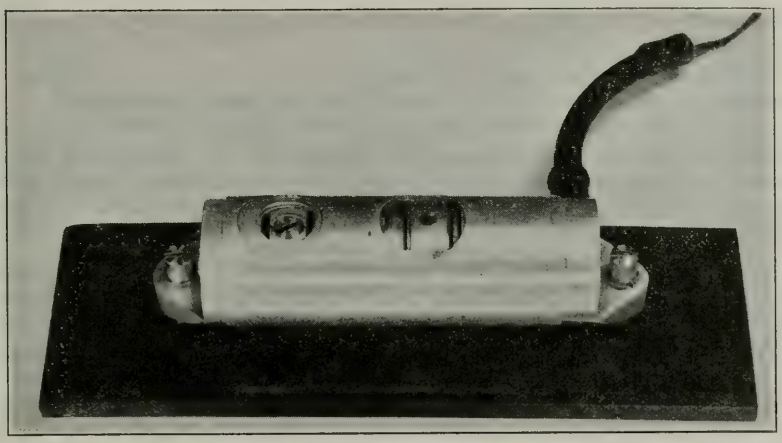


Fig. 37.—View of 4-in. Magnetic Strain Gage Used in Tests of Rail-Joints.

The auxiliary equipment is somewhat varied and complex. The principal auxiliaries are the oscillographs which record graphically the stress variations on photographic films. In the tests on the Pennsylvania Railroad two six-element portable oscillographs were used simultaneously, with the rotating drums containing the films driven by a common shaft and run by one motor. Thus both record films had identical scales of the distances representing the locomotive movement along the track.

To supply current for the instruments and field excitation for the oscillographs a high frequency motor-generator set was used. The equipment required about 150 watts per instrument, most of this being used in the oscillograph field circuit. The gages are connected in parallel and require about 10 volts at 750 cycle frequency. A power supply of 5 kilowatt capacity was needed for the tests but this was larger than would have been necessary if a motor-generator set had not been required to furnish direct current for the high frequency motor-generator set. Since the high frequency supply (750 cycles) was at 120 volts a high freqency transformer was required to supply the proper voltage for the gages. The oscillograph fields were connected in series to the 120 volt 750 cycle supply. It was necessary to have condensers of sufficient capacity in the oscillograph field circuit to obtain similar phase relations for the current in the oscillograph fields and that in the oscillograph elements. This condenser capacity aids in adjusting the current in the oscillograph element to a minimum value and reduces the width of the stress line. When the voltage was removed from the oscillograph fields a

shunt load was automatically placed on the high frequency generator. This reduced speed and voltage variations that would have occurred if the load had been entirely removed.

The oscillograph elements were damped in such a manner that they would not be susceptible to high frequency vibrations but would still indicate correctly the stress variations. As a check on the accuracy of the damped elements, an undamped element was used for several runs. Little if any difference was noted. The damped elements were considered accurate up to variations of stress of 200 cycles per second.

For the higher speed runs a track switch operated by the passage of the locomotive started the oscillograph motor. This placed the records more accurately and conserved film.

Ten inches of the film length were used for each run with the electric locomotive. The drum was rotated about 14.5 seconds for 5 miles per hour, 1.70 seconds for 45 miles per hour, and 1.1 seconds for 70 miles per hour. It was necessary to have the record continue some distance ahead and behind the locomotive in order to locate the zero line of stress. The oscillograph was capable of registering with much higher speeds of rotation of the drum but sufficient separation of stress peaks was obtained at these speeds to show the stress variation accurately.

As mentioned previously the strain gages were attached to studs screwed into holes that had been drilled and tapped in the joint bars at the location selected. The strain gages are adjustable for some variation in distance between the studs. This variation was minimized by using jigs for drilling the holes for the studs. After attachment a total air gap sufficient to record the maximum stress variation (about .030 in.) was set between the two pole pieces and the armature. The armature was adjusted to a central position and locked. These adjustments of distance were all made with the aid of thickness gages. With the strain gages thus adjusted and parts locked in the recording position the power was turned on and the zero stress position of the oscillograph element adjusted so that each gage would indicate in the proper place on the film and have sufficient space to produce its record without interference with the others. The film used for each oscillograph was 7 in. wide and 30 in. long and ordinarily recorded three runs of the locomotive. There were six records of stress on each film and one film had a 60 cycle timing wave at one edge in addition to the six stress records. The timing wave record was useful in obtaining a check on the speed of the locomotive as indicated by the speedometer.

The calibration of the gages was done in the field before and after the tests of the rail-joints, and at other times for check purposes or when instruments had been readjusted or connections transposed. The gages were detached from the studs and mounted one at a time on a calibration device which measured on a dial the movement of the armature due to turning a threaded shaft. Deflections of the oscillograph element due to this movement were recorded on the film in the oscillograph drum, thus giving a permanent record of the calibration. This calibration was the overall constant for the gage and oscillograph element; any rearrangement of the gage connections or change in the total amount of air gap necessitated a new calibration. The constant was ordinarily about 25,000 lb. per sq. in. stress for 1 in. deflection on the film, though the range on the original film records was from 16,000 to 45,000. Calibrations taken at various times checked quite well.

The sensitivity used was by no means the greatest that could have been obtained but was considered the best for the purpose. The accuracy obtained was apparently

limited only by the closeness to which the deflections on the film could be read except in a few cases where some looseness in the adjustments caused vibration and a jagged record. If the deflections on the film were read accurately to .02 in. the stresses would be accurate to about 500 lb. per sq. in.

The cables used to connect the twelve instruments with the oscillographs altogether made up a considerable length. The arrangement was such that the instrument could be placed along a stretch of 300 ft. of track without moving the shelter building which housed the oscillographs and contained a dark-room for film development.

The same 4-in. magnetic strain gages were applied to special extensometer joint bolts (described in Article 22) and indicated satisfactorily the changes in bolt tension at the various speeds.

17. **Conduct of Tests and Reduction of Data.**—One purpose of the tests of rail-joints was to determine the magnitude of the moments taken by the joint bars at mid-section at train speeds. To accomplish this it is essential either that the gage lines be placed at points in mid-section where the measured strains represent the flexural stresses in the joint bar acting as a beam, or as in the case of the inner joint bar where the magnetic strain gage can not be applied to measure directly the real flexural stress in the top portion that a method be available which will permit an allowance to be made in the calculations for the effect of bearing pressure upon the strain at the gage lines. To utilize such a method it is necessary that three gage lines be used at the mid-section of the outer bar. In Fig. 38 are shown the positions of the five instruments

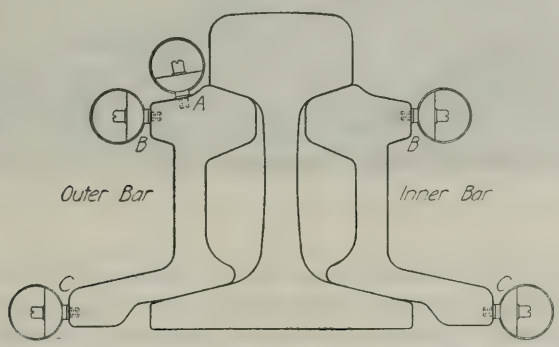


Fig. 38.—Position of Five Magnetic Strain Gages at Mid-Section of Joint Bars.

used at mid-section, and in Fig. 39 a view of six instruments in position on a rail-joint. The magnitudes of the stresses at gage lines *A* and *C* may be used to calculate the bending moments developed in the joint bar by the methods outlined in Article 15 "Methods of Calculations", of the Fifth Progress Report and referred to in Article 4 of this report. By using the measurements at *B* and *C* with either the stress deficiency method or the lateral bending-conversion ratio method (to be described in Article 19 of this report) reduction values for determining moments from *B* and *C* may be obtained which when applied to *B* and *C* of the inner bar in the calculation will give fairly representative values of the moment developed in this bar. The number of magnetic strain gages used was limited to twelve, the number of elements in the two oscillographs. Besides the five at mid-section the instruments were placed to make measurements of stress at sec-

tions 8 in. each way from mid-section. For one of these sections instruments were placed at A and C on the outer joint bar and at B and C on the inner one, and for the other section they were placed at A on the outer joint bar and at B and C on the inner one.

In the tests to determine changes in bolt tension six of the magnetic strain gages were used on the six extensometer bolts and five magnetic strain gages were placed at the five gage lines at mid-section as previously described.

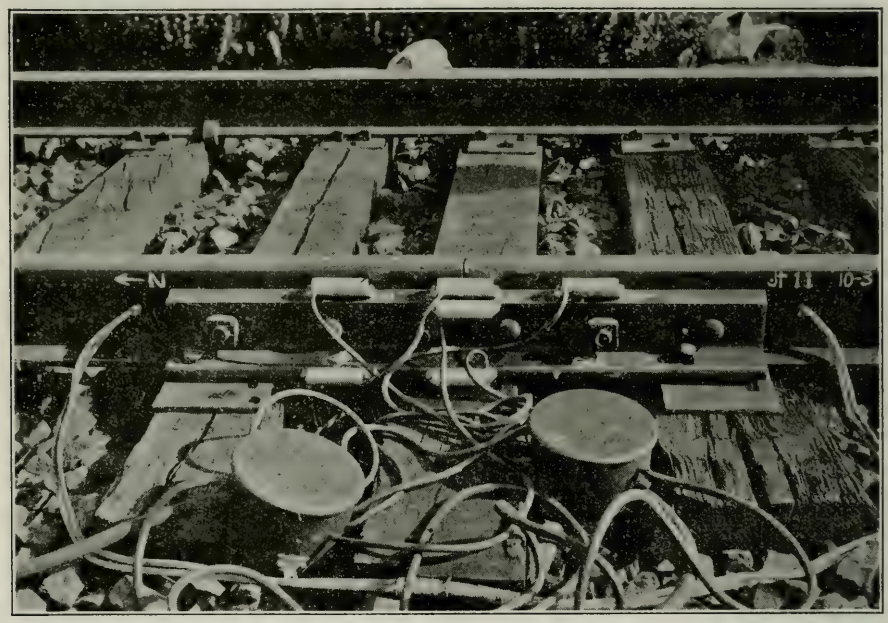


Fig. 39.—View of Six Magnetic Strain Gages in Position on a Rail-Joint.

Constants by which the record of each magnetic strain gage on the film of its corresponding oscillograph element may be converted into stress were obtained by calibration at the test location before, during, and after the tests on the rail-joints, with check calibrations at other times when thought desirable. The films were developed in the dark-room of the shelter building immediately after their exposure.

Except for the most important trains the traffic was diverted from the test track, leaving it free for the conduct of the tests. For a given rail-joint, the usual procedure was to make three or four runs at 5 miles per hour, then the same number at 45 miles per hour, followed with three or four runs at 70 miles per hour, with sometimes one or two at 90 miles per hour, and sometimes additional runs at one speed or another. The speeds were read from the speedometer in the cab of the electric locomotive. The speedometer had been checked with a stop watch in runs over a measured stretch of track and the reported speed was also checked by the timing wave on the oscillograph film.

The tests were made on several rail-joints—in their original condition with bolt tension as found, with joint bars removed from their original joint location and placed

at other joint locations, and with other variations. In Table 7 information is given on the conditions of the joint bars and the designation of the various tests with remarks on the bolt tension, time of installation, etc. (The tensions found in individual bolts of the various joints are given in Table 14 and 15.) See also Fig. 33 for joint locations. Joint 4 was first tested in its original condition with the existing bolt tension (called joint 4-4, meaning joint location 4 and joint bars as found in the track at joint location 4 and its test designated as (a)); then tests were made on the same joint with the tension reduced to 2000 lb. in each bolt (test (b)). The 38½-in. L-3 angle bars of this rail-joint were then cut to a length of 24 in., placed back in track at the same joint location, and test (c) was made on the modified joint 4 still numbered as joint 4-4. Joint 5-5 (joint location 5 and bars 5 as found in the track) with 38½-in. L-3 angle bars was found during test (f) to have the tie-plates at its three joint ties reversed in position from end to end, thus reversing the position of the eccentricity of the tie-plate. As the next tie-plates were laid normally the rail and rail-joint was subject to some twisting action under load. After the tests on this joint had been made the bars were placed at joint location 4 (called joint 4-5) and further tests made, both with the electric locomotive running light (test (d)) and with a train of four heavily loaded cars (test (e)). The laterally deformed angle bars were tested in their original location after ten days service (joint 1-1) (test (g)) and later in joint location 3 (joint 3-1) after having been in this location one day for test (h) and four days for test (i). Joint 9-9 had regular 24-in. L-3 angle bars and was tested as found in the track (test (k)). Joint 11-11 (test (j)) was located on track 1, a track that was not in as good surface condition as the track on which all the other tests were made and apparently had not been surfaced since the previous spring. The tension of the bolts in this joint was low, an average of about 2000 lb. Joint bars of the symmetrical type were placed at joint locations 3 and 2 (joints 3-3 and 2-2, tests (l) and (m)) about five days before their tests were run. It has been noted that joint location 9 was about 60 ft. away from one end of the stretch of track that had been surfaced two months before in preparation for the tests; the lower bolt tension and other characteristics of the joint and the adjacent track indicated that no maintenance work had been applied to this joint and the adjacent track for several months except some relining and surfacing at uneven points in the track preparation made in July.

The first step in the reduction of data was to scale off the ordinate distance to the peak of the stress lines for each film for each instrument from a zero line considered to run between the straight lines at the two ends of the film record well away from the wheel load position. To facilitate the work cross-section paper was slipped under the film and the values read directly from the scale of the paper in hundredths of inches. The readings were later reduced to unit-stress by the use of the reduction factor that had been obtained from the calibration data for each instrument. The values of the stresses reported in this chapter are the actual indications of the instrument, whose effective point of measurement is located ¼ in. away from the surface of the bar. However, in calculating the corresponding moments this offset has been taken into consideration. The peaks of the film diagram were taken to represent the stress with the wheel directly over the instrument except in cases where the record clearly showed vibration along the line—the extent of this vibration was measured at points away from the peak. Readings were also made for the minimum position of the stress line between wheel loads (negative moment). For the instruments at sections 8 in. from the mid-section of the joint bars readings were taken at the peak, which corresponds to the wheel over the instru-

TABLE 7

Designation and Conditions of Rail-Joints and Joint Bars—Tests on Pennsylvania Railroad at Claymont, Delaware

Twelve magnetic strain gages were used on the two bars of a rail-joint unless otherwise stated.

Test Designation	Joint Number	Series	Date of Test	Remarks
(a)	4–4	116–126	9–29	L-3 38½-in. bars. Joint undisturbed since July. Average tension in bolts, 29,000 lb.
(b)	4–4	127–137	9–30	Same L-3 bars. Bolts loosened to about 2000 lb. tension. Thickness gages could be inserted at bar ends.
(c)	4–4	170–178 & 181–182	10– 2	Same L-3 bars but sawed off to 24 in. Installed Oct. 1, 4:00 p. m. Average tension in bolts 28,000 lb.
Special	4–4	179–180	10– 2	Same L-3 24-in. bars. Same bolt tension. Tie-plate over middle tie removed. Speed 5 m. p. h. only.
(d)	4–5	229–238	10– 4	L-3 38½-in. bars changed from joint location 5 Oct. 4, outer bar to outer bar position. 5 gages at mid-length of bars, 6 extensometer bolts. Average tension in bolts 14,000 lb.
(e)	4–5	248–259	10– 6	Same L-3 38½-in. bars taken from joint location 5 on Oct. 4. Average tension in bolts 12,000 lb. Locomotive pulling 4 loaded cars.
(f)	5–5	91–106	9–28	L-3 38½-in. bars. Joint undisturbed since July. The 3 joint tie-plates are found reversed. Test made as found. Average tension in bolts 14,000 lb.
(g)	1–1	138–149	9–30	L-3 38½-in. laterally deformed bars installed about Sept. 20. Average tension in bolts 12,000 lb. Only test at joint location 1.
(h)	3–1	183–192	10– 2	L-3 38½-in. laterally deformed bars taken from joint location 1 and installed in joint location 3 Oct. 2. Average tension in bolts 23,000 lb.
(i)	3–1	242–247	10– 6	L-3 38½-in. laterally deformed bars taken from joint location 1 Oct. 2. 5 gages at mid-length of bars, 6 extensometer bolts. Average tension in bolts 13,000 lb.
(j)	11–11	202–214	10– 3	No. 1 northbound track. L-3 38½-in. bars. Joint undisturbed for several months. Average tension in bolts 2200 lb.
Special	11–11	215–218	10– 3	Same conditions as before except tie-plate over middle tie removed.
(k)	9–9	107–115	9–29	L-3 24-in. bars. Joint undisturbed for several months. Verona springs. Average tension in bolts 6200 lb.
(l)	3–3	150–157	10– 1	38½-in. symmetrical bars installed Sept. 27. Average tension in bolts 14,000 lb.
(m)	2–2	158–169	10– 1	38½-in. symmetrical bars installed Sept. 27. Average tension in bolts 4000 lb. Only test at joint location 2.
(n)	4–5	239–241	10– 4	Same L-3 38½-in. bars as in test (d). Tension in bolts entirely loosened, bars pinched out, then low tension (about 1000 lb.) set in all bolts. 5 gages at mid-section of bars, 6 extensometer bolts.
(o)	9–9	219–225	10 - 4	Same L-3 24-in. bars. Bolts tight. No spring washers. 2 gages at top and bottom of outer bar, 4 P.R.R. extensometer bolts.
(p)	9–9	226–228	10– 4	Same L-3 24-in. bars. Bolts loosened to about 5000 lb. Same set-up.
Special	10–10	193–201	10– 3	Special 26-in. joint bars. Flat spring between bolts 2 to 3. Base plate. 9 gages on bars, 2 on base plate.

ment. In some cases readings were also taken at points corresponding to the position of the wheel load at mid-length of the joint.

The general tests on the rail of the Pennsylvania Railroad with several locomotives at Claymont made in September and October 1930 were conducted by the staff of the Westinghouse Company before and after the tests on rail-joints. In these tests the stresses developed in the rail at different gage lines were measured with 8-in. magnetic strain gages under the moving loads of locomotive and cars. At one section of the track, two magnetic strain gages for each rail were placed on the two edges of the base of rail. At the same section a magnetic strain gage of suitable gage length was placed vertically on each rail, measuring changes in the vertical distance from a point on the outer surface of the head of the rail to a point on the upper surface of the outer flange of the rail. A magnetic strain gage was placed horizontally on the inner face of the web of the rail slightly above the geometrical axis. These vertical and horizontal strain gages were placed on both rails at the one section. Two other magnetic strain gages were placed horizontally on the inner face of the web of one rail at points 33 in. one way and 66 in. the other way from the section of track; two instruments were also placed at corresponding but not opposite positions on the other rail. The speeds used in the tests with the electric locomotive were 5, 45, 70 and 90 miles per hour, and in two runs 100 miles per hour. For the steam locomotives tests were made at 5, 45, 70, and 80 or 90 miles per hour. These are probably the highest speeds at which measurements of stresses developed in rail have ever been made. The records of these measurements of stress in rail were reduced by the Westinghouse Company and used for determining the running characteristics of the several electric locomotives at the various speeds and for making comparisons with the running characteristics of two types of steam locomotives of the Pennsylvania Railroad.

18. **Stresses in Joint Bars.**—In Fig. 40 is shown a film record of the magnetic strain gages at the two edges of the base of rail (¼ in. above bottom) as the electric locomotive moved past the instrument at a speed of 45 miles per hour. This diagram is reduced only slightly from the original film record. The vertical scale of each stress measurement is indicated. The zero line of stress has been drawn by connecting the two straight line portions of the far ends of the record; for the line drawn in the figure the measurements of stress are made to the upper edge of the width of the record, whether for tension or compression. The peak values of the record correspond to the stress immediately under a wheel and their ordinates give the tensile stress developed; the ordinates on the other side of the zero line give the compressive stress where negative moment is developed. Both stresses are measured from the same side of the record line. It may be noted that the vertical width of the line is nearly the same at all places so that the same results may be obtained by the use of either the upper or the lower side of the line. The mean stress under the two drivers was 14,400 lb. per sq. in. The shape of the diagram from left to right corresponds to the form of the curve of stresses found from analytical calculations, as is seen in Fig. 41.

In Fig. 42 is shown a film record of the magnetic strain gages at gage lines *A*, *B* and *C* at mid-section of the outer angle bar of joint 3-1 (test (i)) as the electric locomotive moved past the instrument at a speed of 45 miles per hour, together with a record of tension in bolt 4. The time taken by the locomotive in moving through the distance represented by the length of the record shown in Fig. 42 is 1.1 seconds, and the distance 73 ft. This diagram is about two-thirds the scale of the original film record. The zero line of stress has been drawn in the usual way by connecting the two straight

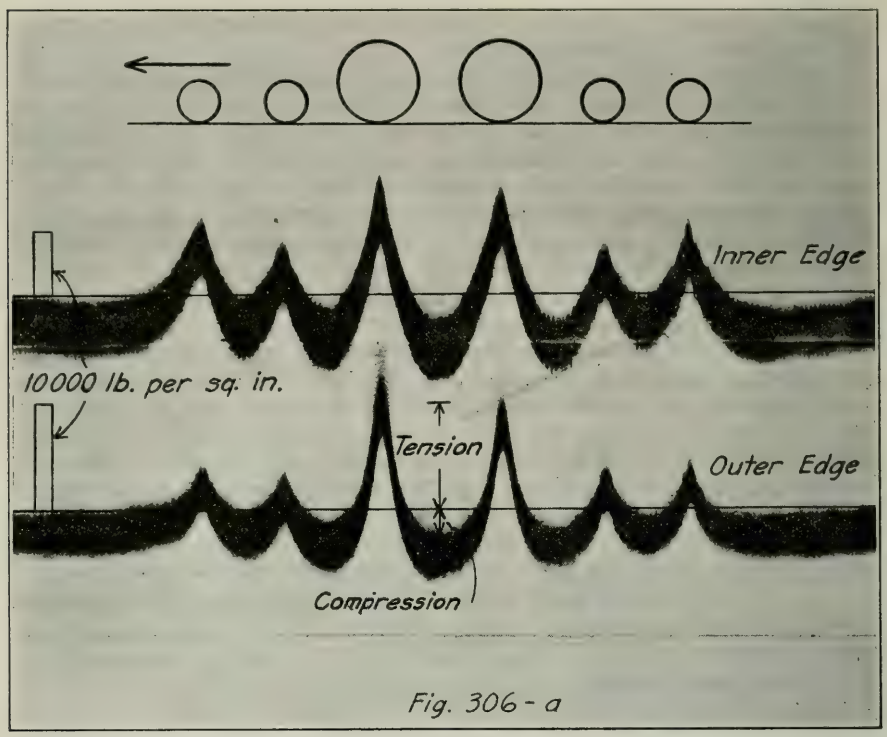


Fig. 40.—Film Record of Stresses at the Two Edges of Base of Rail Measured by the Magnetic Strain Gages—Speed 45 Miles Per Hour.

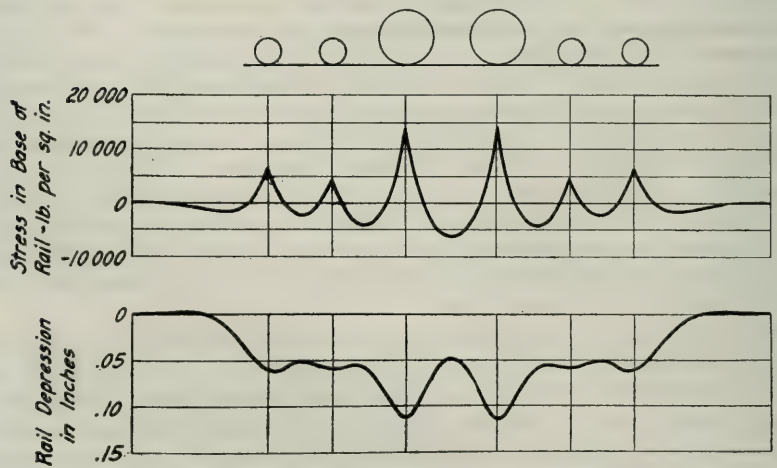


Fig. 41.—Magnitude and Distribution of Analytical Stresses and Rail Depression for Electric Locomotive 7850.

line portions of the record that are outside and away from the diagram shown in the figure; for the zero line drawn in the figure the measurements of stress are made to that edge of the width of the record into which the line merges. The peaks of the record correspond to a position of the wheels immediately over the instrument, and their ordinates multiplied by the scale for each instrument give the stress developed; the ordinates on the other side of the zero line give the stress where negative moment is developed.

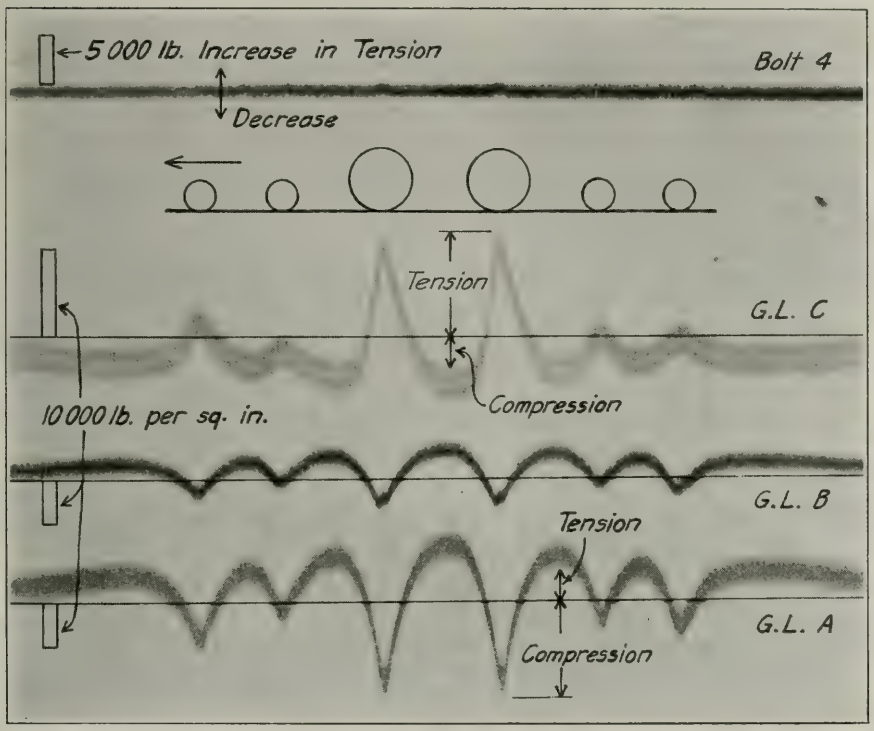


Fig. 42.—Film Record of Stresses at Gage Lines *A*, *B* and *C* at Mid-Section of the Outer Angle Bar of Joint 3—1 as Measured by the Magnetic Strain Gages—Speed 45 Miles Per Hour.

The vertical scale of stresses generally differs for the different individual records; in this diagram the scale is approximately the same for gage lines *A* and *B*, but that for *C* is considerably larger, as is seen by comparing the vertical scales equivalent to 10,000 lb. per sq. in. indicated in the figure. The ordinates from the zero line for the peaks for *A* and *B* indicate compression and those for the peaks for *C* tension. Between wheels the stresses change from compression to tension in *A* and *B* and from tension to compression in *C*. In each case all stresses are measured from the same zero line. The shape of the diagram from wheel to wheel and the general form of the stress curves for the joint bars are similar to those shown in the preceding figure for the rail, with the same kind of changes in stress from one wheel to another. The diagram in Fig. 42 is typical of the records found with all of the joints tested except, of course, for the rela-

tions of the magnitudes at the several gage lines and for the relative values of horizontal and vertical scales, and the form of the record is indicative of the flexural action at mid-section.

TABLE 8

Observed Stresses at Mid-Section in L-3 Angle Bars for 130-lb. P.S. Rail—Tests on Pennsylvania Railroad at Claymont, Delaware with Electric Locomotive 7850

The stresses in thousands of pounds per square inch are given for outer and inner bar. The average at the two drivers for the several runs at a given speed is reported. The letters *A*, *B* and *C* refer to the gage line for which the stress is recorded.

Test Desig.		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)
Joint Number		4–4	4–4	4–4	4–5	4–5	5–5	1–1	3–1	3–1	11–11	9–9
Bolt Tension		High	Low	High	High	High	High	High	High	High	Low	Low
Condition				Cut to 24″	Extn Bolts	With 4 Cars	Tie-Plate Rev'd	Lat. Def.	Lat. Def.	Lat. Def.	Track 1	
5 m.p.h.												
Outer	A	15.7	11.0	16.8	18.3	17.2	16.1	24.6	24.0	25.4	13.6	11.9
	B	7.6	8.1	5.2	5.2	6.6	8.3	10.6	7.9	8.7	6.2	8.1
	C	6.2	4.5	3.9	8.2	12.0	15.3	10.7	10.1	9.8	4.7	5.3
Inner	B	10.3	7.6	9.9	8.6	12.4	14.6	10.8	10.3	11.2	5.5	10.2
	C	11.4	9.3	0.4	4.3	6.8	4.8	13.6	10.8	6.5	7.8	5.6
45 m.p.h.												
Outer	A	15.2	14.1	20.0	16.9	18.2	16.5	21.7	23.1	22.2	13.5	15.4
	B	7.2	7.7	6.1	4.9	7.6	7.8	10.7	8.7	7.8	6.4	12.0
	C	7.0	6.8	3.6	11.1	10.8	13.0	10.2	10.0	11.4	6.1	6.1
Inner	B	12.3	10.0	8.3	12.4	10.9	12.8	9.5	10.1	12.9	6.7	12.2
	C	11.7	4.2	3.1	4.1	9.6	6.4	12.5	8.1	5.5	6.8	7.3
70 m.p.h.												
Outer	A	15.9	14.6	20.0	17.3	17.0	19.9	25.0	24.4	21.2	13.1	13.4
	B	7.2	5.9	6.0	5.0	6.4	8.3	9.2	8.7	8.3	8.3	9.4
	C	7.7	8.2	5.7	13.5	12.6	14.0	13.1	11.4	7.4	5.5	4.6
Inner	B	12.1	11.0	10.3	16.0	12.1	14.1	13.0	11.8	8.5	4.5	7.5
	C	12.8	3.7	5.0	3.2	8.5	7.3	13.8	8.4	7.1	8.2	6.0
90 m.p.h.												
Outer	A	14.6*	19.4†					36.1*	18.3*			
	B	6.9	-------					-------	8.1			
	C	4.8	8.9					19.9	6.5			
Inner	B	7.5	11.5					12.5	6.7			
	C	13.0	4.4					13.7	8.8			

*One run only. †Two runs.

In Table 8 are given the observed stresses at gage lines *A*, *B* and *C* at mid-section of the angle bars, including the regular 38½-in. L-3 bars, those cut to 24 in. length, the laterally deformed bars, the 24-in. L-3 bars (joint 9-9) on track 4 away from the regular test track, and joint 11-11 on track 1. The values given are the averages for the two drivers and the several runs at a given speed. In Table 9 are given the similar average stresses in the symmetrical joint bars at gage lines *A*, *B* and *C* of mid-section, for which it should be remembered the coordinates differ from the general values for the

angle bars—especially for gage line *C*. In general, in all these tests, the average value given is for three or more runs at the given speed, except for the speed of 90 miles per hour and for a few cases where only one or two runs were made or where a record was questionable. It should be noted that the value 36,000 lb. per sq. in. for gage line *A* of the outer angle bar for joint 1-1 and a speed of 90 miles per hour represents only one run; it appears that the locomotive at this high speed gave values much more irregular than at lower speeds.

TABLE 9

Observed Stresses at Mid-Section of Penn. Symmetrical Bars for 130-lb. P.S. Rail—Tests on Pennsylvania Railroad at Claymont, Delaware with Electric Locomotive 7850

The stresses in thousands of pounds per square inch are given for outer and inner bar. The average at the two drivers for the several runs at a speed given in miles per hour is reported. The letters *A*, *B* and *C* refer to the gage lines for which the stress is recorded.

Test Desig.		(l)			(m)		
Joint Number		3–3			2–2		
Bolt Tension		High			Low		
Speed		5	45	70	5	45	70
Outer	A	20.2	19.5	19.9	13.4	10.2	9.9
	B	8.1	8.0	7.4	6.1	6.4	5.6
	C	4.0	3.5	6.0	4.5	4.4	7.1
Inner	B	8.5	7.6	10.9	5.9	5.5	9.1
	C	11.9	11.4	10.9	12.7	13.7	13.5

The compressive stresses in gage line *A*, which is near the highest point of the bars, are of course greater than those at the other gage lines and in several instances reach 25,000 lb. per sq. in. The stresses at gage line *B* are considerably smaller; this may be expected from its lower position and especially from the effect of the bearing pressure of the rail on the top fishing surface at and near the mid-section, as has been discussed heretofore. The effect of the bearing pressure is found to vary greatly with the different joints, and in some cases it varies considerably with the different speeds. The stresses at gage line *C* vary considerably depending upon the position taken by the neutral axis and probably also upon the lateral bending.

The stresses in the angle bars, measured at the several speeds, showed inclinations of the neutral axis similar to those found in laboratory and field tests under static loading. In the tests here reported the application of lateral bending moments due both to the condition of the rail support and to the way in which the wheel load was applied in a given run necessarily produced a variety of values of the inclination of the neutral axis, but the range in results was much the same as has been found with static loading.

The stresses in the bars at sections 8 in. away from mid-section, as measured from the records of the magnetic strain gages, agreed in general form and magnitude with the measured stresses with advancing wheel load found in the laboratory and previous field tests under static loading. The longitudinal scale of the records, however, makes it difficult to obtain accurate simultaneous values at the different sections when the load is at mid-section.

In making comparisons between joints or in determining the effect of speed, the magnitude of the stress at one gage line alone can not well be used because of the variability in the action of the different joints and variations in the application of load at different places and in different runs. Instead, the magnitude of the moment developed at a mid-section will be taken as the basis of comparison in the discussion of moments in joints in the following article.

19. **Moments in Rail-Joints.**—The variability in the action of joint bars by reason of differences in the inclination of the neutral axis and the effect of the bearing pressure of the head of the rail on the top fishing surface of the bar when load is applied make comparisons of rail-joints by means of measured stresses rather indefinite and unsatisfactory. Instead, the magnitudes of the moments developed in the joint bars as calculated from the measured stresses will be used. Reference is made at the end of Article 4 "The Function and Action of the Rail-Joint" to equation (67) and its use with two measured stresses considered as true flexural stresses, and in Article 11 "Distribution of Stresses over Vertical Section at and near Mid-Length" comparisons are made between the applied moment and the calculated moment in the laboratory tests of various rail-joints. It was shown that for a measured stress near the top point of the bar (say, gage line *A*, Penn. L-3, Fig. 3) and one on the lower part of the bar (say, gage line *C*) the calculated moment at mid-section does not differ greatly from the applied moment, but that when the upper gage line is at one side of the top point of the bar (say, gage line *B*) there is a considerable deficiency in the calculated moment. It was further shown that when the rail ends were moved apart so that the bearing of the head of the rails on the bars is well away from mid-length of the bars, the approximate value of the applied moment is given by calculations with the measured stresses at either of the upper gage lines, *A* or *B* and the stress at gage line *C*. The averages of the ratios in Tables 3, 4 and 5 are given as conversion ratios. When the moment obtained by equation (67) and the measured stresses at gage lines such as *B* and *C* is multiplied by the conversion ratio for the given rail-joint, the resulting value approximates closely to the applied moment for the conditions of the laboratory tests.

With the rail-joint in track the conditions may vary considerably from those of the laboratory tests. The bearing of the rail on the tie-plate or of tie-plate on tie may be eccentric and uneven and lateral bending and twisting may exist, both because of the eccentricity of support and of loading and because of the lateral forces applied by the wheel loads. For the outer bar the measured strains at gage lines *A* and *C* (or at other gage lines similarly situated with respect to the position of the bearing surface at the top of the bar at mid-length) will be assumed to be representative of the real flexural stresses at mid-section and no conversion ratio need be used for the field tests where great refinement is not warranted. For the inner bar where the strain at gage line *B* is the available measurement for the top portion of the bar, some method must be used to allow for the effect of bearing pressure upon the strain developed at gage line *B* at and near mid-section. The only information available in the field tests is the relation between the values given by gage line *A* and gage line *B* for the outer bar, and with the use of this relation must go the assumption that the inner bar acts in the same way as the outer bar or that their variation in action is in accordance with a lateral moment or other assumed difference.

After considering several methods of calculation, two methods of conversion for the moments of the inner bar at mid-section have been chosen—method A, the stress deficiency method, and method B, the method by use of lateral moments. In method A, the

bearing pressure of rail on bar upon application of load is considered to create a longitudinal tensile strain at gage line B which decreases the measurable compressive flexural stress in this gage line. From the data of gage lines A, B and C for the outer bar of any rail-joint and the assumption that gage lines A and C give the correct moment, the average stress deficiency of the stress at gage line B needed to give the correct moment by B and C is determined for the outer bar, generally for each speed used in the runs; this value of stress deficiency is then added to the observed value at B in the inner bar and the stress so found is used with the stress at C in the inner bar in making the calculations of moment in the inner bar at mid-section by means of equation (67). It will be seen that method A assumes that the effect of bearing pressure is the same in the inner bar as in the outer. The deficiency stress used will be expected to vary with different test loads.

In method B, the bearing loads are considered to affect the strain at gage line B at and near mid-section in a manner similar to an individual lateral bending of the bar itself, or at least that the value of the calculated lateral moment obtained from measured strains at B and C will be affected in magnitude proportionally to a lateral bending moment calculated from the measured strains at B and C. From the data of the outer bar, the moment ratio $\frac{A\&C}{B\&C}$ (ratio of vertical moment obtained from gage line A and C to that obtained from B and C) is plotted as ordinate and the lateral bending moment by calculation from B and C by equation (68)* as abscissa for each joint or type of joint and sometimes for each speed, and lines are drawn to represent the average trend of the plotted points. With the analytical lateral moment of the inner bar obtained from the stresses at gage line B and C (equation (68)), the diagram is then entered for the corresponding moment ratio $\frac{A\&C}{B\&C}$, and this value is used as the conversion ratio by which the values of the vertical moment obtained from gage line B and C by equation (67) is multiplied in obtaining the final value of the vertical moment for the inner bar.

Neither method A or method B takes into account the lateral bending of the rail-joint as a whole. In some respects method A seems to have rational characteristics, in others method B takes into account peculiarities of the action of a joint bar. The

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* Equation (68) for calculating the lateral bending moment developed in an unsymmetrical section of joint bar in terms of the measured stresses s_1 and s_2, at any two points of a section, x_1, y_1 and x_2, y_2, (the locations of which are chosen preferably at two points of high stress on opposite sides of the neutral axis, as for example gage lines A and C or B and C of the section of Penn. L-3 joint bars in Fig. 3) may be obtained by substituting in equation (44) the value of tan α given in equation (55), both to be found in the Fifth Progress Report. The equation is

$$M_y = \left(\frac{J_{xy}x_2 - I_y y_2}{y_1 x_2 - x_1 y_2}\right) s_1 + \left(\frac{I_y y_1 - J_{xy} x_1}{y_1 x_2 - x_1 y_2}\right) s_2 \quad . \quad . \quad . \quad . \quad (68)$$

where M_y is the lateral moment (resisting moment about a vertical gravity axis of the bar), x_1 and y_1 are the abscissa and the ordinate of the point in the section for gage line 1 taken with reference to the horizontal and vertical geometrical axes of the section, and x_2 and y_2 are similarly the coordinates for gage line 2, and s_1 and s_2 are the corresponding measured stresses, respectively, at the two gage lines.

moments obtained for the inner bar by either method do not appear to be far wrong. As before stated, the moment calculated from gage lines *A* and *C* approximates closely to the value of the moment developed in the outer bar. In the absence of information on the stress at gage line *A* in the inner bar, the vertical moment developed in the rail-joint at mid-section will be taken as the sum of the moment calculated for the outer bar from gage lines located like *A* and *C* without further reduction or conversion and the moment for the inner bar from gage lines *B* and *C* with the stresses or moments modified by the use of method A or method B, which takes into account properties of the same type of joint obtained from the stress data of the outer bar. Finally, the average of the values obtained by the two methods will be used in the comparison of the rail-joints.

It should be noted that it was shown in Article 11 "Distribution of Stresses over Vertical Section at and near Mid-Length" (see Table 3) that the observed stress at gage line *A* for mid-section is smaller than the real flexural stress and that the moments calculated from the observed stresses at gage line *A* and *C* in laboratory tests of angle bars taken from the track at Claymont average about 7 per cent smaller than the applied moments. As great refinement is not warranted in the reduction of the data of the field tests, the observed stress at *A* has been taken to be the real flexural stress. It is probable then that the moments hereinafter reported may be on the average 5 or even 10 per cent smaller than the actual moment, and because values at gage line *A* are involved in the conversion method this statement is applicable also to the moments in the inner bar.

It does not seem necessary to give the many details of methods A and B used in the reduction and conversion of the data of all the runs of the tests. A brief statement concerning the general values of the stress deficiency and the conversion ratio may be useful in judging of variations found. The following values approximate to the average value of the stress deficiency used in method A: tests (a) and (b), 6000; tests (c), (d), (e), 12,000 to 7000; test (f), 5000; tests (g), (h), (i), 11,000; test (j), 5000; test (k), 2000—all in pounds per square inch of stress which is added to the observed value of stress at gage line *B* of the inner bar before making the calculation of the moment in the inner bar. The following are the average values of the conversion ratios used in method B for multiplying the moments obtained from gage lines *B* and *C* of the inner bars to find the moment by this method, though the ratios used vary above and below these values according to values of the calculated lateral moments found in this inner bar: test (a), 1.20; (b), 1.45; (c) and (d), 2.20; (e), 1.50; (f), 1.40; (g), 1.40; (h) and (i), 1.80; (j), 1.35; and (k), 1.10.

In Table 10 are given the values of the moments developed in the outer and inner joint bars at mid-section under the first and second drivers by method A and method B for each run made at the several speeds for the Penn. L-3 rail-joints used in tests (a) to (k), and in Table 11 the values of the similar moments in the Penn. symmetrical bars by method A in tests (l) and (m). (See Table 7 for test conditions of the rail-joint.) For the lower speeds the variation between the several runs is not large. For higher speeds the variation is greater—in some cases considerably greater, due probably to the variability in the transfer of load from one driver to its companion on the same axle and to transfer from wheel to wheel on the same rail usual at such speeds, as the locomotive runs along the track. The data in Tables 10 and 11 show the variations from run to run at the various speeds. The information is useful in making detailed comparisons of the moments developed in the various rail-joints and their variations, especially at the higher speeds. The effect of speed will be discussed in Article 20.

TABLE 10

Vertical Bending Moments at Mid-Section in L-3 Angle Bars for 130-lb. P.S. Rail—Tests on Pennsylvania Railroad at Claymont, Delaware with Electric Locomotive 7850

Moments are given in thousands of inch-pounds for outer and inner bar and the sum. The grand average for each rail-joint does not include the results at 90 miles per hour. Values of moment for the inner bar were calculated by conversion methods A and B.

Series and Speed	Method A						Method B					
	First Driver			Second Driver			First Driver			Second Driver		
	Outer	Inner	Sum	Outer	Inner	Sum	Outer	Inner	Sum	Outer	Inner	Sum
(a) Joint 4 - 4. High bolt tension.												
5 m.p.h.												
116	83	110	193	87	113	200	83	108	191	87	106	193
117	90	116	206	91	114	205	90	112	202	91	109	200
118	88	116	204	91	115	206	88	112	200	91	108	199
Av.	87	114	201	90	114	204	87	111	198	90	108	198
45 m.p.h.												
120	93	133	226	86	116	202	93	128	221	86	112	198
121	93	127	220	86	117	203	93	122	215	86	113	199
122	92	126	218	82	118	200	92	122	214	82	110	192
Av.	93	129	221	85	117	202	93	124	217	85	112	196
70 m.p.h.												
123	85	115	200	90	126	216	85	120	205	90	117	207
124	92	132	224	112	145	257	92	115	207	112	121	233
125	86	122	208	96	132	228	86	116	202	96	114	210
Av.	88	123	211	99	134	234	88	117	205	99	117	217
90 m.p.h.												
126	98	125	223	63			98	110	208	63	87	150
Grand Av.	89	122	211	91	122	213	89	117	206	91	112	203
(b) Joint 4 - 4. Bolt tension 2,000 lb.												
5 m.p.h.												
128	63	86	149	67	87	154	63	70	133	67	71	138
129	64	86	150	70	89	159	64	75	139	70	73	143
136	56	57	113	56	54	110	56	62	118	56	55	111
Av.	61	76	137	64	77	141	61	69	130	64	66	130
45 m.p.h.												
130	83	88	171	78	80	158	83	93	176	78	83	161
131	91	86	177	81	71	152	91	92	183	81	73	154
132	86	85	171	79	71	150	86	89	175	79	73	152
Av.	87	86	173	79	74	153	87	91	178	79	76	155
70 m.p.h.												
133	101	92	193	110	102	212	101	116	217	110	135	245
135	80	75	155	80	77	157	80	93	173	80	93	173
137	84	85	169	77	78	155	84	109	193	77	97	174
Av.	88	84	172	89	86	175	88	106	194	89	108	197
90 m.p.h.												
127	111	114	225	62	71	133	111	113	224	62	64	126
134	137	129	266	142	120	262	137	131	268	142	140	282
Av.	124	121	245	102	95	197	124	122	246	102	102	204
Grand Av.	79	82	161	77	79	156	79	89	168	77	83	160

TABLE 10—Continued

Series and Speed	Method A						Method B					
	First Driver			Second Driver			First Driver			Second Driver		
	Outer	Inner	Sum	Outer	Inner	Sum	Outer	Inner	Sum	Outer	Inner	Sum
(c) Joint 4 - 4. Bars cut to 24 in. length. High bolt tension.												
5 m.p.h.												
170	89	87	176	89	85	174	89	108	197	89	104	193
171	86	93	179	86	95	181	86	120	206	86	120	206
172	91	90	181	91			91	113	204	91		
Av.	89	90	179	89	90	179	89	114	203	89	112	201
45 m.p.h.												
173	107	110	217	103	100	203	107	123	230	103	89	192
174	90	106	196	99	95	194	90	121	211	99	91	190
175	115	109	224	105	100	205	115	124	239	105	102	207
Av.	104	108	212	102	98	200	104	123	227	102	94	196
70 m.p.h.												
176	115	116	231	117	127	244	115	144	259	117	153	270
177	111	115	226	123	127	250	111	143	254	123	153	276
178	80	87	167	108	102	210	80	85	165	108	106	214
181	106	126	232	113	136	249	106	143	249	113	146	259
182	97	111	208	107	121	228	97	119	216	107	123	230
Av.	102	111	213	114	123	237	102	127	229	114	136	250
Grand Av.	98	103	201	102	104	206	98	121	219	102	114	216
(d) Joint 4 - 5. Bars from joint location 5. Extensometer bolts used. High bolt tension.												
5 m.p.h.												
230	100	105	205	99	101	200	100	123	223	99	108	207
231	102	106	208	101	100	201	102	122	224	101	103	204
233	103	113	216	103	109	212	103	141	244	103	124	227
234	108	119	227	104	113	217	108	149	257	104	131	235
Av.	103	111	214	101	108	209	103	134	237	101	116	217
45 m.p.h.												
232	100	114	214	97	106	203	100	163	263	97	123	220
235	99	120	219	104	119	223	99	178	277	104	148	252
236	109	121	230	109	114	223	109	180	289	109	141	250
Av.	103	118	221	103	113	216	103	174	277	103	137	240
70 m.p.h.												
237	108	125	233	125	136	261	108	194	302	125	184	309
238	103	118	221	107	122	229	103	187	290	107	168	275
Av.	105	121	226	116	129	245	105	190	295	116	176	292
Grand Av.	104	117	221	107	117	224	104	166	270	107	143	250
(e) Joint 4 - 5. Bars from joint location 5. High bolt tension. Locomotive pulling four loaded cars.												
5 m.p.h.												
248	105	112	217	104	117	221	105	128	233	104	124	228
249	105	117	222	105	117	222	105	132	237	105	122	227
250	110	123	233	110	123	233	110	137	247	110	126	236
Av.	107	117	224	106	119	225	107	132	239	106	124	230
18 m.p.h.												
251	109	123	232	111	127	238	109	137	246	111	128	239
252	106	118	224	113	129	242	106	129	235	113	131	244
253	108	116	224	108	123	231	108	121	229	108	119	227
254	104	115	219	109	126	235	104	124	228	109	122	231
255	108	118	226	111	128	239	108	127	235	111	125	236
Av.	107	118	225	110	127	237	107	128	235	110	125	235

TABLE 10—Continued

Series and Speed	Method A						Method B					
	First Driver			Second Driver			First Driver			Second Driver		
	Outer	Inner	Sum	Outer	Inner	Sum	Outer	Inner	Sum	Outer	Inner	Sum
45 m.p.h.												
256	108	132	240	105	120	225	108	146	254	105	121	226
257	110	123	233	108	120	228	110	136	246	108	122	230
258	111	130	241	109	124	233	111	143	254	109	126	235
259	111	128	239	96	117	213	111	141	252	96	114	210
Av.	110	128	238	105	120	225	110	141	251	105	121	226
Grand Av.	108	121	229	107	122	229	108	134	242	107	123	230
(f) Joint 5 -5. Tie-plates found reversed. High bolt tension.												
5 m.p.h.												
91												
92												
93												
94	103	94	197	106	98	204	103	108	211	106	115	221
95	103	101	204	106	100	206	103	114	217	106	116	222
96	103	99	202	107	98	205	103	113	216	107	115	222
103	116	112	228	117	117	234	116	126	242	117	133	250
104	112	109	221				112	122	234			
105	110	112	222				110	123	233			
106	113	113	226	115	114	229	113	126	239	115	131	246
Av.	109	106	215	110	105	215	109	119	228	110	122	232
45 m.p.h.												
97	113	116	229	101	102	203	113	122	235	101	109	210
98	112	113	225	99	99	198	112	119	231	99	106	205
99	112	116	228	97	99	196	112	121	233	97	105	202
Av.	112	115	227	99	100	199	112	121	233	99	107	206
70 m.p.h.												
100	131	130	261	118	106	224	131	137	268	118	140	258
101	119	124	243	123	133	256	119	129	248	123	147	270
102	132	139	271	119	115	234	132	144	276	119	122	241
Av.	127	131	258	120	118	238	127	137	264	120	136	256
Grand Av.	116	117	233	110	108	218	116	126	242	110	122	232
(g) Joint 1 - 1. Laterally deformed angle bars. High bolt tension.												
5 m.p.h.												
139	143	148	291	142	152	294	143	142	285	142	147	289
140	133	148	281	137	156	293	133	142	275	137	148	285
141	143	145	288	145	152	297	143	140	283	145	147	292
148	128	155	283	136	153	289	128	143	271	136	150	286
Av.	137	149	286	140	153	293	137	142	279	140	148	288
45 m.p.h.												
142	137	139	276	143	131	274	137	132	269	143	137	280
143	104	135	239	125	131	256	104	129	233	125	137	262
144	106	132	238	138	129	267	106	126	232	138	132	270
149	118	151	269	120	139	259	118	144	262	120	147	267
Av.	116	139	255	131	132	263	116	133	249	131	138	269
70 m.p.h.												
145	153	156	309	157	153	310	153	149	302	157	147	304
146	146	174	320	143	164	307	146	161	307	143	157	300
147	146	177	323	129	168	297	146	160	306	129	165	294
Av.	148	169	317	143	162	305	148	157	305	143	156	299

TABLE 10—Continued

Series and Speed	Method A						Method B					
	First Driver			Second Driver			First Driver			Second Driver		
	Outer	Inner	Sum	Outer	Inner	Sum	Outer	Inner	Sum	Outer	Inner	Sum
90 m.p.h.												
138	214			225	166	391	214	146	360	225	162	387
Grand Av.	134	152	286	138	149	287	134	144	278	138	147	285
(h) Joint 3 - 1. Laterally deformed angle bars from joint location 1. High bolt tension.												
5 m.p.h.												
183	124	139	263	127	145	272	124	142	266	127	148	275
184	129	139	268	133	148	281	129	144	273	133	150	283
191	143	148	291	147	152	301	143	156	299	149	163	312
Av.	132	142	274	136	148	284	132	147	279	136	154	290
45 m.p.h.												
186	137	127	264	122	109	231	137	136	273	122	113	235
187	135	151	286	122	133	255	135	161	296	122	144	266
Av.	136	139	275	122	121	243	136	148	284	122	128	250
70 m.p.h.												
188	124	139	263	140	158	298	124	145	269	140	166	306
189	131	111	242	143	128	271	131	111	242	143	138	281
190	141	148	289	155	165	320	141	157	298	155	179	334
Av.	132	133	265	146	150	296	132	138	270	146	161	307
90 m.p.h.												
192	113	111	224	86	116	202	113	129	242	86	104	190
Grand Av.	133	138	271	135	140	275	133	144	277	135	148	283
(i) Joint 3 - 1. Laterally deformed angle bar from joint location 1. Extensometer bolts. High bolt tension.												
5 m.p.h.												
242		128			141			135			143	
243	136	122	258	138	137	275	136	126	262	138	137	275
246	145	131	276	145	145	290	145	139	284	145	150	295
Av.	140	127	267	141	141	282	140	133	273	141	143	284
45 m.p.h.												
244	129	131	260	129	129	258	129	148	277	129	148	277
245	132	128	260	126	128	254	132	143	275	126	149	275
Av.	130	129	260	127	128	255	130	145	275	127	148	275
70 m.p.h.												
247	124	124	248	106	103	209	124	135	259	106	104	210
Grand Av.	131	127	258	125	124	249	131	138	269	125	132	257
(j) Joint 11 - 11. Track 1. Low bolt tension.												
5 m.p.h.												
202	79	90	169	85	87	172	79	81	160	85	74	159
203	84	93	177	81	88	169	84	86	170	81	79	160
210	65	80	145	79	86	165	65	75	140	79	75	154
211	63	76	139	77	81	158	63	74	137	77	72	149
214	67	86	153	76	90	166	67	76	143	76	76	152
Av.	72	85	157	80	86	166	72	78	150	80	75	155

TABLE 10—Continued

Series and Speed	Method A						Method B					
	First Driver			Second Driver			First Driver			Second Driver		
	Outer	Inner	Sum	Outer	Inner	Sum	Outer	Inner	Sum	Outer	Inner	Sum
45 m.p.h.												
204	83	98	181	84	88	172	83	94	177	84	89	173
205	78	80	158	73	75	148	78	76	154	73	72	145
206	75	80	155	75	77	152	75	76	151	75	75	150
Av.	79	86	165	77	80	157	79	82	161	77	79	156
70 m.p.h.												
207	105	91	196	82	64	146	105	75	180	82	65	147
208	63	67	130	48	56	104	63	66	129	48	58	106
209	63	67	130	61	55	116	63	69	132	61	59	120
212	98	100	198	69	77	146	98	87	185	69	74	143
213	85	84	169	87	82	169	85	77	162	87	72	159
Av.	83	82	165	69	67	136	83	75	158	69	66	135
Grand Av.	78	84	162	75	78	153	78	78	156	75	73	148
(k) Joint 9 - 9. 24-in. L-3 angle bars. Low bolt tension. Not on prepared stretch of track.												
5 m.p.h.												
107	66	64	130	72	81	153	66	69	135	72	79	151
108	63	67	130	73	81	154	63	70	133	73	81	154
109	64	65	129	75	81	156	64	71	135	75	81	156
Av.	64	65	129	73	81	154	64	70	134	73	80	153
45 m.p.h.												
110	87	87	174	80	86	166	87	82	169	80	82	162
111	87	89	176	87	89	176	87	84	171	87	85	172
112	86	79	165	97	85	182	86	77	163	97	86	183
Av.	87	85	172	88	87	175	87	81	168	88	84	172
70 m.p.h.												
113	77	66	143	94	88	182	77	67	144	94	89	183
114	65	52	117	77	62	139	65	53	118	77	58	135
115	63	61	124	71	72	143	63	58	121	71	66	137
Av.	68	60	128	81	74	155	68	59	127	81	71	152
Grand Av.	73	70	143	81	81	162	73	70	143	81	78	159

In Table 12 are given in summary form the averages of the values at the two drivers and for all the runs at a given speed for the tests with L-3 joints; the corresponding averages for the Penn. symmetrical bars are given in Table 11. In discussing the values of these moments, one comparison that is useful is that made with the average moment developed in the full rail itself on this track with the given locomotive used in the tests. The calculated value of the moment in rail on the basis of u equal to 4000 and a weight on each driver of 37,500 lb. is 330,000 in.-lb. This value will be used as the base in making comparisons and in computing the joint moment ratio (ratio of the magnitude of moment in rail-joint developed by a given loading to the general value of the moment correspondingly developed in rail on the same stretch of track). The value of the moment in rail based on the stresses under the drivers obtained by the Westinghouse engineers at one section in each rail for one run at 5 miles per hour was 300,000

TABLE 11

Vertical Bending Moments at Mid-Section in Penn. Symmetrical Bars for 130-lb. P.S. Rail—Tests on Pennsylvania Railroad at Claymont, Delaware with Electric Locomotive 7850

Moments are given in thousands of inch-pounds for outer and inner bar and the sum. Values of moments for the inner bar were calculated by conversion method A.

Series and Speed	First Driver			Second Driver			Average Moment in Two Bars for the Two Drivers
	Outer	Inner	Sum	Outer	Inner	Sum	
(l) Joint 3 - 3. High bolt tension.							
5 m.p.h.							
150	82	107	189	79	105	184	
151	83	107	190	83	109	192	
152	83	109	192	83	112	195	
Av.	83	108	190	82	109	190	190
45 m.p.h.							
153	84	107	191	68	92	160	
154	91	108	199	71	94	165	
155	84	109	193	74	94	168	
Av.	86	108	194	71	93	164	179
70 m.p.h.							
156	85	104	189	87	117	204	
157	75	101	176	87	119	206	
Av.	80	102	182	87	118	205	193
(m) Joint 2 - 2. Low bolt tension.							
5 m.p.h.							
158	58	84	142	52	78	130	
159	59	88	147	52	85	137	
160	59	89	148	55	74	129	
167	61	78	139	56	88	144	
Av.	59	85	144	54	81	135	139
45 m.p.h.							
161	45	72	117	48	73	121	
162	45	72	117	44	70	114	
163	45	67	112	51	71	122	
168	44	70	114	35	57	92	
Av.	45	70	115	45	68	112	114
70 m.p.h.							
166	46	83	129	42	84	126	
165	42	82	124	40	82	122	
164	53			54	65	119	
Av.	47	82	127	45	77	122	124

in.-lb., but the calculated value named above is probably more nearly representative of the general value of the moment along the stretch of track. A tabulation of the joint moment ratios found in the tests is given in Table 13.

TABLE 12

Summary of Vertical Moments at Mid-Section in L-3 Angle Bars for 130-lb. P.S. Rail—Tests on Pennsylvania Railroad at Claymont, Delaware with Electric Locomotive 7850—Average for the Two Drivers of All Runs at a Given Speed

Moments are given in thousands of inch-pounds for outer and inner bar and the sum. Moments for the inner bar were taken as the means of the values obtained by conversion methods A and B.

Test Desig.	(a)	(b)	(c)	(d)	(e)*	(f)	(g)	(h)	(i)†	(j)‡	(k)
Joint Number	4–4	4–4	4–4	4–5	4–5	5–5	1–1	3–1	3–1	11–11	9–9
Bolt Tension	High	Low	High	High	High	High	High	High	High	Low	Low
Condition			Cut to 24 in.	Extn. Bolts	With Four Cars	Tie-Plate Rev'd	Lat. Def.	Lat. Def.	Lat. Def.	Track 1	
5 m.p.h.											
Outer	88	62	89	102	106	109	138	134	140	76	68
Inner	112	72	101	117	123	113	148	147	136	81	74
Sum	200	134	190	219	229	222	286	281	276	157	142
45 m.p.h.											
Outer	89	83	103	103	107	105	123	129	128	78	87
Inner	120	81	106	135	127	111	136	133	138	81	84
Sum	209	164	209	238	234	216	259	262	266	159	171
70 m.p.h.											
Outer	94	88	108	110		123	145	139	115	76	74
Inner	122	96	124	154		131	161	146	116	72	65
Sum	216	184	232	264		254	306	285	231††	148	139

*Five runs at 18 miles per hour gave moments of 108,000, 125,000, and 233,000 in.-lb. in inner bar, outer bar, and two bars, respectively.
†With extensometer bolts.
‡24-in. L-3 angle bars not on prepared stretch of track.
††One run at 70 miles per hour.

In test (a) joint 4-4 (joint location 4 with bars found in joint 4, see Fig. 33), the condition of the rail-joint may be considered as normal for this stretch of test track—the bars were well fitting, the bolts were tight, the tie support apparently firm and having little play between rail and tie. The average value of the moment developed in two joint bars at mid-section for the runs at 5 miles per hour is 200,000 in.-lb.; this gives a joint moment ratio of .61. This ratio is within the range of the joint moment ratios found in tests of good track and reported in the Fifth Progress Report—perhaps somewhat below the average value for the best joints reported. In test (b) joint 4-4 (the same joint with bolt tension reduced to approximately 2000 lb.) the average moment developed in the joint bars at 5 miles per hour was 134,000 in.-lb. with a corresponding joint moment ratio of .41, a value 33 per cent less than that found with tight bolts. The lower bolt tension did not draw the bars into good contact with the rail for the full length of the bars and the thickness gages showed play between bar and rail head at and near the ends of the bars. The play between bar and rail evidently allowed the rail ends to deflect somewhat under the part of the application of load before the joint

TABLE 13

Joint Moment Ratios at Mid-Section in Two L-3 Angle Bars for 130-lb. P.S. Rail—Tests on Pennsylvania Railroad at Claymont, Delaware with Electric Locomotive 7850—Average for the Two Drivers

The speed is given in miles per hour. The base of the ratio is 330,000 in.-lb.

Test Designation	Joint Number	Joint Moment Ratio 5	45	70	90	Remarks
(a)	4–4	.58	.64	.62	.65	High bolt tension.
		.62	.64	.70		
		.61	.62	.64		
		Av. .61	.63	.65	.65	
(b)	4–4	.43	.50	.65	.54	Bolt tension 2,000 lb.
		.45	.50	.50	.81	
		.34	.49	.53		
		Av. .41	.50	.56	.68	
(c)	4–4	.55	.64	.76		Bars cut to 24 in. length.
		.58	.59	.76		High bolt tension.
		.58	.66	.57		
				.75		
				.67		
		Av. .57	.63	.70		
(d)	4–5	.63	.68	.83		Bars from joint location 5.
		.64	.73	.77		Extensometer bolts used.
		.68	.75			High bolt tension.
		.70				
		Av. .66	.72	.80		
(e)	4–5	.68	.71			Bars from joint location 5.
		.68	.71			High bolt tension. Locomotive pulling four loaded cars.
		.72	.73			
			.69			
		Av. .69	.71			
(f)	5–5	.63	.66	.77		Tie-plates found reversed.
		.64	.65	.77		High bolt tension.
		.64	.65	.77		
		.72				
		.71				
		Av. .67	.65	.77		
(g)	1–1	.87	.83	.92	1.18	Angle bars laterally deformed.
		.86	.75	.94		High bolt tension.
		.88	.76	.92		
		.85	.80			
		Av. .87	.78	.93	1.18	
(h)	3–1	.81	.76	.70	.65	Laterally deformed angle bars from joint location 1. High bolt tension.
		.84	.83	.79		
		.91		.94		
		Av. .85	.80	.86	.65	
(i)	3–1	.81	.81	.70		Laterally deformed angle bars from joint location 1, extensometer bolts. High bolt tension.
		.87	.80			
		Av. .84	.80	.70		
(j)	11–11	.50	.53	.50		Track 1. Low bolt tension.
		.51	.45	.36		
		.45	.46	.38		
		.45		.51		
		.46		.50		
		Av. .47	.48	.45		
(k)	9–9	.43	.51	.49		24-in. L-3 angle bars. Low bolt tension. Not on prepared stretch of track.
		.44	.52	.39		
		.43	.52	.39		
		Av. .43	.52	.42		

began to take moment proportional to the load applied. It should be noted, however, that the moments developed at speeds higher than 5 miles per hour approach those developed in test (a).

With the same bars sawed off to a length of 24 in. (test (c)) and bolts quite tight, the moment developed at mid-section was almost the same as in test (a), though the stress at the lower gage line was less, showing a difference in fit between bar and rail in the two cases and a change in restraint which would affect the action of an unsymmetrical bar. It is not to be expected that the moment developed in the shorter bars would be much different from that of the longer ones provided the fit of the bars was equally good. It is possible that subjection to traffic for a long period of time would develop differences not shown in this test.

The two tests with joint 4-5 (tests (d) and (e)) give values quite alike—the pulling of loaded cars would not be expected to change the magnitude of the moment developed—change of bolts from extensometer bolts to ordinary bolts without loosening the joint bars should not cause differences. The moment developed in the joint bars at 5 miles per hour was 219,000 and 229,000 in.-lb., corresponding to an average joint moment ratio of .68. The magnitude of the moment developed in joint bars 5 in their original position (test (f)) was approximately the same as that found with the same bars in joint location 4 (the joint moment ratio also being about the same)—evidently somewhat a matter of chance, for not only do two joint locations give differences in supporting conditions but the reversal of the tie-plates found in joint location 5 would be expected to produce abnormal conditions of bending.

In tests with joint bars 1 at joint location 1 and 3 (tests (g), (h), and (i)), the moments developed at mid-section of the bars designated as laterally deformed were greater than found in the tests previously mentioned. At 5 miles per hour the moments in the three tests are 286,000, 281,000 and 276,000 in.-lb., which correspond to joint moment ratios of .87, .85 and .84. The bars were unusually well fitting. The high value of the joint moment ratio seems not to be attributable to the form of the bars, unless the bearings of the deformed bars were such as to relieve the joint ties of part of their load. The bars had been in joint location 1 only ten days and in joint location 3 one and four days for tests (h) and (i), respectively, and the condition of the tie support for the recently installed bars may have been the source of the high values.

The low values of the moment in test (k) joint 9-9 with 24-in. L-3 angle bars, corresponding at 5 miles per hour to a joint ratio of .43, are not unusual in track that is considered good track in ordinary condition. Joint location 9 was away from one end of the stretch of track that had been prepared for the test work. At this place the rail and joint bar were two years old and had been subjected to heavy high-speed traffic, the ties at the joint were spaced further apart (22 and 25¾ in.) than those just beyond (20 and 19 in.), and surfacing had not been done recently. The measured tensions were 7000, 5000, 4000 and 21,000 in the four bolts. Play existed in one half of the length of the bars, as shown by thickness gages, but the high tension in one bolt held the other half well in place. The looseness of the tie-plate on the ties at or near one end of the rail-joint showed that these ties had been permanently depressed, but the joint would not be considered a low joint. It is well to note that the presence of low joint moment ratios represents undesirable conditions, which must lead to decreasing effectiveness in tie support and thus to injury to both rail ends and substructure.

The rail-joint on track 1 (the northbound passenger track; test (j) joint 11-11) was found to have low bolt tension (900, 1700, 1500, 3600, 5100 and 400 lb.). Thickness

gage measurments showed play between rail and bar. The rail and bars had been in track two years. The joint bars were 38½ in. long. The ties at the rail ends are spaced closer, 16 and 16 in., as compared with the spacing of 21 and 25 in. for the adjacent tie either way. The moment developed at mid-section of the bars at a speed of 5 miles per hour was 157,000 in.-lb. The corresponding joint moment ratio is .47. It should be added that neither joint 11-11 nor joint 9-9 was a "low joint", so far as was noticeable to the eye.

In test (l) joint 3-3 (Penn. symmetrical bars) the bolts had retained nearly full tension for the four days since installation. The moment developed under the drivers at 5 miles per hour (190,000 in.-lb., joint moment ratio of .58) is 68 per cent of that developed in the same joint location with the laterally deformed L-3 bars (tests (h) and (i)). The source of this difference is not apparent; though as joint 3-3 was fairly free from play the smaller stiffness of these symmetrical bars as compared with the L-3 bars would tend to decrease the moment developed at mid-section as compared with that developable in the L-3 bars under otherwise similar conditions. The joint moment ratios in tests (h) and (i) are, of course, unusually high.

The bolts of joint 2-2 (test (m), Penn. symmetrical bars) had lost most of their tension in the four days they had been installed. The moment developed under the drivers at 5 miles per hour (139,000 in.-lb.) corresponds to a joint moment ratio of .42. The low bolt tension and the relatively small moment of inertia in this joint and the conditions of the fit on the base of rail probably contributed to the lowness of the joint moment ratio, but the conditions of the tie supports may also have had a part.

The tests were made on joints having a variety of conditions with the view of finding something of their characteristics under moving load at various speeds and also to learn the effect of speed upon stresses and moments. The number of tests was not large enough to determine ranges in the values or even averages. For information of this kind reference may be made to the tests with static loading reported in the Fifth Progress Report of the Committee on Stresses in Railroad Track with 130-lb. and 127-lb. rail. In 20 consecutive joints on the Delaware, Lackawanna and Western Railroad on track that was not specially prepared for the tests and on which no work had been done for a considerable time the joint moment ratio ranged from .62 to .90 and averaged .75. In 7 joints on the New York Central Railroad on track in good condition but not specially prepared for the test yet having more unevenness from point to point the joint moment ratio ranged from .49 to .79 and averaged .62. These values and ranges may be considered as examples of what may exist on high grade track.

It should be added that the form of the curves of bending moment at mid-section of the joint bars when the locomotive passes by the instrument, as calculated from the observed stresses at top and bottom of bar, corresponds closely at all speeds to the curve of moments determined from analytical considerations. For the different speeds the ratio of the negative moment to the positive moment developed varies in the different joints, sometimes being greater than normal and sometimes less, depending principally upon the variation in rail support from tie to tie near the joint.

20. **Effect of Speed.**—For determining the effect of speed upon the stresses and moments developed in rail-joints, it is apparent that data from a considerable number of runs at each speed would be needed in drawing conclusions. For purposes of comparison there should also be data available for the stress in the rail opposite the joint taken simultaneously with the stresses in the joint and preferably also on the two rails at one or two places well away from the joint. Especially at the higher speeds, it is

known that a transfer of load occurs from wheel to wheel on the same axle and to a lesser extent from wheel to wheel longitudinally of the rail, as the locomotive moves along the track, and this change in wheel load complicates comparisons and increases the variability of results. The limitations of the test program did not permit this auxiliary information to be obtained. At 5 miles per hour, however, the stresses may be expected to correspond closely to the static loads of the wheels and their spacing. In the tests it was found that at the highest speeds the stresses in rail were quite variable, as shown by the data of the Westinghouse engineers, indicating considerable shifting of weight, and in the joint tests at 90 miles per hour and in some of those at 70 miles per hour the moment developed in the joint bars averaged even lower than at 5 and 45 miles per hour. The number of runs over a given joint in the tests at Claymont was not sufficient to give full information, and as nothing is known of the stresses in the rail opposite a joint the shifting of load from one end of an axle to another cannot be considered. The tests, however, do furnish information from which the trends of the effects of speed and important conclusions may be stated.

The values of the joint moment ratio (ratio of moment in two bars at mid-section to the general value of the moment in full rail elsewhere for static loading) are given in Table 13 for each run for the several joints from the moments recorded in Table 10, the tabulated value being the average for the two drivers by the methods A and B. These ratios will be used as a convenient basis of comparison. It is apparent that increases in moments in these joints due to speed are not large—quite in contrast to what has sometimes been thought to be the case. The average value of the ratios for the different speeds for the different tests is plotted in four groups in Fig. 43. The tests in each group are in some degree comparable.

Test (a) on joint 4-4 with high bolt tension (a well fitting joint) with very consistent data shows an increase from 5 miles per hour to 70 miles per hour of 7 per cent of the ratio at 5 miles per hour; the differences between extreme values for individual runs and the average value are generally not more than 10 per cent of the average value for that speed. In Fig. 43, it is seen that the increase in moment in test (a) is closely proportional to the changes in speed—7 per cent increase from 5 to 70 miles per hour. Test (b) on the same joint with low bolt tension shows an increase of 37 per cent from 5 to 70 miles per hour; the variation from run to run at 70 miles per hour is also quite small. Although this increase is much larger than in test (a), the joint moment ratio at 70 miles per hour still is less than for test (a), but it may be expected that the effect on the track substructure will be much greater than in test (a). Test (c) with the bars cut to a length of 24 in. gave an increase of 23 per cent for a speed of 70 miles per hour.

Tests (d), (e) and (f) are fairly comparable. The increase to 70 miles per hour in tests (d) and (f) averages 18 per cent; at 45 miles per hour the change is small. Here again the variation in the ratios for the several runs was small. Five runs in test (e) at 18 miles per hour gave values almost the same as at 5 and 45 miles per hour.

The group of tests (g), (h) and (i) gave similar joint moment ratios at 5 miles per hour (averaging about .85), which, as has already been noted, are considerably higher than those found in the other joints. At 45 miles per hour, slight decreases have occurred, but the three tests are closely grouped. In test (g) the ratio at 70 miles per hour is an increase of 7 per cent over that at 5 miles per hour. In test (h) at 70 miles per hour considerable variation is found and the joint moment ratio ranges from .70 to .94. In the one run of test (h) at 90 miles per hour the joint moment ratio was only

.65. In test (i) the one run at 70 miles per hour gave a ratio of only .70. These variations for the higher speeds may be attributed in part to transfers of load from wheel to wheel on the same axle for the runs recorded.

Tests (j) and (k) were made on joints that had lower bolt tension and that had been in track for some time so that the tie and ballast supports probably had been forced down to fit the changing condition in the fit of the joint. In the tests of both joints

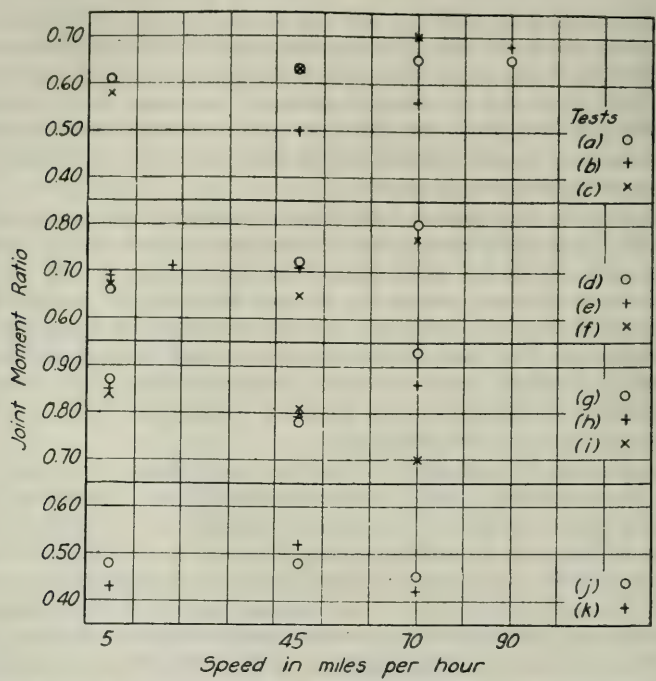


Fig. 43.—Joint Moment Ratios Developed at Various Speeds in Tests at Claymont, Delaware.

the joint moment ratio changed generally little with speed; in test (j) the ratios at the three speeds were .47, .48, and .45, and in test (k) .43, .52, and .42. In the latter test the value at 45 miles per hour is 21 per cent greater than that at 5 miles per hour. It seems probable that the smallness of values at 70 miles per hour is due to transfers of wheel load in the runs, as may also be expected to be the case for the low value of a run at 90 miles per hour.

It may be added that the highest value of the joint moment ratio obtained was 1.18 in. the one run of test (g) at 90 miles per hour. Except for this value the joint moment ratio developed in the joints did not reach unity and thus never came up to the general value to be expected for the moment in full rail at 5 miles per hour. The general rate of increase to 70 miles per hour with tight bolts is less than 20 per cent, though in further runs greater transfers of load to the joint from the other rail might have been encountered. On the whole the increase in stress and moment in these joints with

speed for the locomotive used may be called small. It should be noted, of course, that this locomotive gave little or no counterbalance effect on the rail. It may be added that the rate of increase in moment in the joint bars noted in these tests is comparable with the rate of increase in moment in rail with increase in speed for tests with electric locomotives made on the Chicago, Milwaukee and St. Paul Railway reported in the Fourth Progress Report and smaller than most of the other speed effects reported for tests on rail with other locomotives and with cars.

21. **Bolt Tension in the Rail-Joints.**—Tension was measured in the regular 1⅛-in. bolts of the rail-joint while in an unloaded condition by means of the caliper extensometer described in Article 6, and also by means of the Berry strain gage on the special extensometer bolts in a few tests. Changes in bolt tension under moving loads were measured with these special extensometer bolts and the magnetic strain gages, as will be described in the next article.

In Table 14 are given the tensions in thousands of pounds measured in the regular bolts in the unloaded rail-joints. Bolt 1 is at the north end of a joint, and for the 4-bolt bars the numbers 2 and 5 are omitted for test (k) and 1 and 6 for test (c). In tests (a) and (f) the bolts had probably not been wrenched up for two months and in (j) and (k) probably not for a longer time. In test (b) the bolts had been adjusted just before the test to the lesser tension noted; the second measurement gives the tension after the set of runs had been completed. For test (c) the sawed-off bars had been installed the day before the test was made with traffic running over the joint in the meantime; the tension was measured after the test runs were completed. For test (e) the bars from joint location 5 were installed at joint location 4 two days before the test was run and the tension was measured after the test runs were completed. For test (g) the bars had been installed ten days before and the bolt tension was measured directly after the test. For test (h) the installation and the test and the measurement were made on the same day. For tests (l) and (m) installation of bars was made five days before and measurement of tension made just after the test. The runs named in the column of Remarks correspond to series numbers in Table 7.

It is seen from the data of Table 14 that the tension existing in the bolts in the joints as found in the track was quite variable from joint to joint and from bolt to bolt. In test (a) (joint 4-4) the inner bolts had tensions of approximately 20,000 and 15,000 lb., the intermediate bolts 43,000 and 49,000 lb., and the end bolts 21,000 and 26,000 lb. The end and the inner bolts with tensions of 15,000 to 26,000 lb. may be termed "high"; the tension in the intermediate bolts is "extremely high", higher than the limits of useful tension indicated by the laboratory tests of the springing of the bars discussed in Article 10. In test (f) (joint 5-5) the tensions found, averaging 14,000 lb. and ranging between 9400 and 20,600 lb., are reasonably uniform and apparently sufficiently high. Only close observation would show that the bolts of joint 11-11 of track 1 (test (j)) had low tension. The end bolts had tension of less than 1000 lb. and the other bolts from 1500 to 5000 lb. The use of the thickness gage showed some vertical space between outer bar and rail toward the ends of the bar, but the inner bar seemed to fit fairly well. One rail end had been moving in the joint with temperature changes. Verona spring washers were found on joint 9-9 (test (k)). The bolt tension at one end of the bar was 7000 and 5000 lb. and at the other 4000 and 21,000 lb. It may be recalled that the joint moment ratios in tests (j) and (k) averaged about .46 at 5 miles per hour.

TABLE 14

Bolt Tension in Rail-Joints of Pennsylvania Railroad at Claymont, Delaware

Measurements were made with caliper extensometer. Tension is given in thousands of pounds.

Test Desig.	Jt. No.	Type of bars	Bolt Number 1	2	3	4	5	6	Remarks
(a)	4–4	L-3 38½	20.8	43.5	19.8	14.9	48.6	25.7	Measured after run 126. Joint undisturbed since July.
(b)*	4–4	L-3 38½	3.8	3.0	4.6	6.6	2.6	2.5	Tension set to this amount before run 127.
(b)†	4–4	L-3 38½	1.9	1.3	1.8	3.4	1.2	2.0	Measured after run 137.
(c)	4–4	L-3 24		19.3	44.4	24.6	22.8		Measured after runs 170-182. Bars taken from joint location 4, sawed off to 24″ and reinstalled Oct. 1.
(e)	4–5	L-3 38½	14.6	9.3	8.0	8.0	21.3	10.2	Measured after runs 248-259. Bars taken from joint location 5, and installed at joint location 4, Oct. 4.
(f)	5–5	L-3 38½	9.4	20.6	19.9	14.2	9.6	11.1	Measured after runs 91-106. Joint undisturbed since July. Tie-plates found to be reversed from end to end.
(g)	1–1	L-3 38½ Lat. def.	15.9	13.4	9.3	5.7	13.8	12.5	Measured after runs 138-149. Installed about Sept. 20.
(h)	3–1	L-3 38½ Lat. def.	25.0	21.8	11.9	18.7	30.5	28.2	Measured after runs 183-192. Bars taken from joint location 1 and installed at joint location 3, Oct. 2.
(j)	11–11	L-3 38½	.4	5.1	3.6	1.5	1.7	.9	Measured after runs 202-218. No. 1 track. Rail laid 1929.
(k)	9–9	L-3 24	6.9		5.5	3.5		21.5	Measured after runs 107-115. Verona springs. Bolts probably not tightened for several months.
(l)	3–3	Sym. 38½	8.9	13.7	23.5	2.7	32.6	16.4	Measured after runs 150-157. Installed 5 days before test.
(m)	2–2	Sym. 38½	1.6	2.7	6.4	8.4	.2	4.2	Measured after runs 158-169. Installed 5 days before test.

*Measurement before making the runs of test (b).
†Measurement after making the runs of test (b).

In test (b) with the bolts unwrenched until the bolt tension measured just after the test averaged 2000 lb., the joint moment ratio fell to .41—test (a) gave .61 at 5 miles per hour under the same conditions except for bolt tension. Although the bars fit well in test (a), at the time of test (b) a thickness gage could be inserted at places along the bar and there was evidently vertical play between bar and rail. The lack of fit accompanying the low bolt tension permitted deflection of joint with correspondingly lessened stiffness of the joint and small moment-producing quality. Test (c) (bars sawed to 24 in.) with high tension in the four bolts gave about the same joint moment ratio as test (a). At the same joint location, the bars from joint location 5 and with a bolt tension moderate to high (tests (d) and (e)) gave a joint moment ratio of .68 at 5 miles per hour somewhat higher than the ratios found in tests (a) and (c) and about the same as that developed at the original location of these joint bars.

With the laterally deformed L-3 bars (tests (g), (h) and (i)) the tension was generally moderately high except that the inner bolts of joint 1-1 were lower and two of the bolts at one end of joint 3-1 were quite high. As was discussed in Article 19, the fit of this joint was excellent, but it is not apparent how much the high joint moment ratio (.85 at 5 miles per hour) was dependent upon fit or whether a camber or other unusual condition may have added to the moment developed.

The symmetrical type bars in test (l) fit well, though they apparently rested on the base of rail and not on the rail fillet as was intended in the design. The bolt tension averaged 16,000 lb., with one very high and one low bolt tension. The joint moment ratio developed was .58 as compared with .85 for tests (h) and (i) at the same joint location. For test (m) (joint 2-2) it is apparent that the bars had moved and readjusted their position with respect to the rail after the bolt tension was applied and before the time of the test so that the tension fell off greatly. The tension at the time of the test ranged from 200 to 8400 lb. The fit at the bottom was not good. These conditions apparently contributed to the lowness of the joint moment ratio, .42.

In Table 15 are given the tensions measured in the special extensometer bolts when installed in joints 4-5 and 3-1 both before and after certain test runs were made. The bolts were tightened to give approximately even tension in the six bolts. As was found in laboratory tests, during the first few loadings the tension fell off, owing to the opportunities for readjustment in the position of the bars with respect to the rail by reason of the differences in the flexure of the rail and the bar from point to point along the length. In test (d) the drop in tension ranges from 1500 to 7700 lb. and in test (i) from 5700 to 11,900 lb. There is indication that the loss in the end bolts is less than that in the others. The laboratory tests have shown that the loss of tension with additional loadings becomes smaller and smaller. Test (d) is directly comparable with test (e), and test (i) with test (h). The bolt tensions for each pair of tests are roughly comparable in their effects, and the joint moment ratios developed in each pair have correspondingly equal or similar values.

The use of the two measurements made at the two points beyond the two extreme elements of the special extensometer bolts furnishes information on the bending stresses put into the bolts by the tightening operation and brings out an indication of the unevenness and eccentricity of bearing that exists at both ends of the bolts and at the spring washers. In the bottom part of Table 15 are given the extreme fiber bending stresses in the horizontal plane (found by taking half the difference between the stresses at the two extreme fibers) for the twelve bolts in tests (d) and (i). The bolts had been wrenched up with unusual care and for most of the bolts the bending stresses are not large. The highest values of the stresses due to bendings are 11,000, 13,000 and 17,000 lb. per sq. in., which added to the average tensile stress in the bolt makes maximum fiber stresses of 35,000, 26,000 and 42,000 lb. per sq. in., respectively, in the three worst cases. It was noted that in these tests the bending stress in a bolt measured after a test is almost the same in amount as that measured initially, even though the tension in the bolt as a whole has dropped off materially. In some bolts the stress at one extreme fiber of the extensometer bolt was zero and that on the opposite fiber was double the average stress, which itself represents the effective tension in the bolt. The bending measured and reported was all in the horizontal plane through the axis of the bolt; bending in other planes would also exist, and that in the vertical plane will probably be greater than that in the horizontal plane. It should be borne in mind that these tests were made with accurately machined bolts and full finished nuts so that the eccentricity was

TABLE 15

Tension and Bending Stresses in Bolts of Rail-Joints of Pennsylvania Railroad at Claymont, Delaware

Measurements were made on the special extensometer bolts by means of a Berry strain gage. Bolt tension is given in thousands of pounds. The bending stresses at the extreme horizontal fibers of the bolts, reported in the lower part of the table, are given in thousands of pounds per square inch. Bars are L-3 38½-in. angle bars. Test (i) was made with laterally deformed bars.

Test Desig.	Jt. No.	Bolt Number 1	2	3	4	5	6	Remarks
		Bolt Tension						
(d)	4–5	12.4	25.3	11.8	20.0	17.3	20.7	Measured before run 229.
(d)	4–5	10.9	18.1	8.5	12.3	14.8	18.1	Measured after run 238.
		1.5	7.2	3.3	7.7	2.5	2.6	Reduction in tension by runs 229-238.
(n)	4–5	1.6	.8	.7	.1	.3	2.1	Bolts loosened after run 238. Measured after runs 239-241.
(i)	3–1	22.7	27.6	21.4	21.7	15.5	22.8	Measured 50 min. before run 242.
(i)	3–1	15.2	16.5	9.5	11.2	9.8	15.6	Measured after run 247A.
		7.5	11.1	11.9	10.5	5.7	7.2	Reduction in tension by runs 242-247.
		Bending Stresses						
(d)	4–5	3.0	5.5	13.5	8.9	1.7	5.9	Bending stress measured before run 229.
(d)	4–5	2.1	7.0	11.6	8.0	2.4	5.8	Bending stress measured after run 238.
(i)	3–1	17.3	3.5	1.3	0.7	3.4	10.8	Bending stress measured 50 min. before run 242.
(i)	3–1	16.3	3.7	1.0	0.9	1.8	10.9	Bending stress measured after run 247A.

due to the bearing on bars and spring washers and not to the bolts themselves. With the ordinary track bolt and ordinary wrenching the opportunities for the higher eccentricities and greater bending stresses would doubtless be increased. It should not be overlooked that the stresses at the threads are materially larger than those reported in the tables.

The Pennsylvania flat spring washers which were used in all the rail-joints except at joint location 9 closed down at a pressure of say 2000 lb. and gave little or no springing action at bolt tensions higher than this. The Verona spring washers used in the regular tests at joint location 9 had been flattened part way down, but the amount of elastic spring remaining in them was not measured. It was not apparent that the Pennsylvania standard spring washers had been instrumental in maintaining bolt tension in the joints as found in the track. In tests (o) and (p) at joint location 9, no washers were used with the special Pennsylvania extensometer bolts.

As before stated the data of the measured bolt tensions show marked variation and irregularity from bolt to bolt and joint to joint. The existing tensions varied from 200 to 49,000 lb. and in a single joint from 15,000 to 49,000 lb. and from 3000 to 33,000 lb.

It is obvious that it is extremely difficult to get an initial uniform tension in the four or six bolts of a joint, and the changes in position of the bar with respect to the rail made in the later adjustment under the bending effects of repeated loadings and unloadings will not be uniform for the several bolts, thus making variability in tension more marked after traffic has had its effect. The difficulty and uncertainty continue with later wrenching but in some respects the irregularities in the tensions become smaller. Regardless of the magnitude of the bolt tension this variability may not be troublesome if the tension is adequate for holding the bars in a position which ensures proper stiffness of joint and proper moment producing conditions, and these properties depend to a considerable degree on the shape and fit of the bars. It is very evident that the springing action of the bars under bolt tension aids in maintaining the tension in the bolts and thus in keeping the bars in proper position and contact with the rail.

22. **Changes in Bolt Tension under Moving Loads.**—The effect of moving loads upon the magnitude of the tension in the bolts of a rail-joint has long been a matter of interest and opinion and speculation—whether the tension increases or decreases under the passing load and especially whether it increases markedly at medium and high speeds. Information on the subject will have bearing on the action of the joint and on the function of the bolt, whether to hold the bars in proper contact and maintain the right fit or whether the forces acting during the passage of the load produce high tensions in the bolts that will have to be provided for. Static load tests (see Fifth Progress Report for results of laboratory tests) have shown certain increases and decreases in the tension upon application of load, with the magnitudes of the changes relatively small.

In order to determine the changes in tension in the joint bolts developed during the passage of the wheels of a locomotive or cars over a rail-joint at various speeds from low to high, the six special extensometer bolts heretofore referred to were designed so that the magnetic strain gages that were used in measuring stresses in the joint bars could be attached and used for giving autographic records of the tension in the individual bolts. The principle of the action of these special extensometer bolts is the same as for those described in Article 6 "The Laboratory Tests of Rail-Joints", but the form was adapted to the mounting of the magnetic strain gage used in the tests of joint bars, rather than a dial gage.

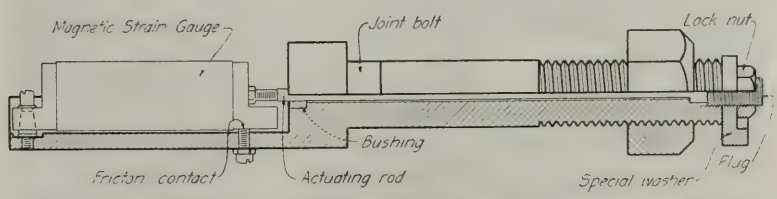


Fig. 44.—Diagrammatic Representation of Special Extensometer Bolt.

Fig. 44 is a diagrammatic representation of the special extensometer bolt. Fig. 45 shows a single extensometer bolt with the magnetic strain gage in place. Fig. 46 is a view of six extensometer bolts applied to a joint in the field tests. The body of the extensometer bolt is made of special alloy steel (3135 S.A.E. chrome nickel steel) heat-treated to give a high elastic limit and still retain sufficient toughness for shock resist-

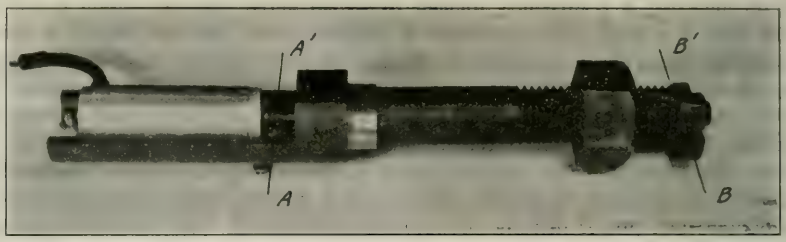


Fig. 45.—View of Special Extensometer Bolt with Magnetic Strain Gage Attached.

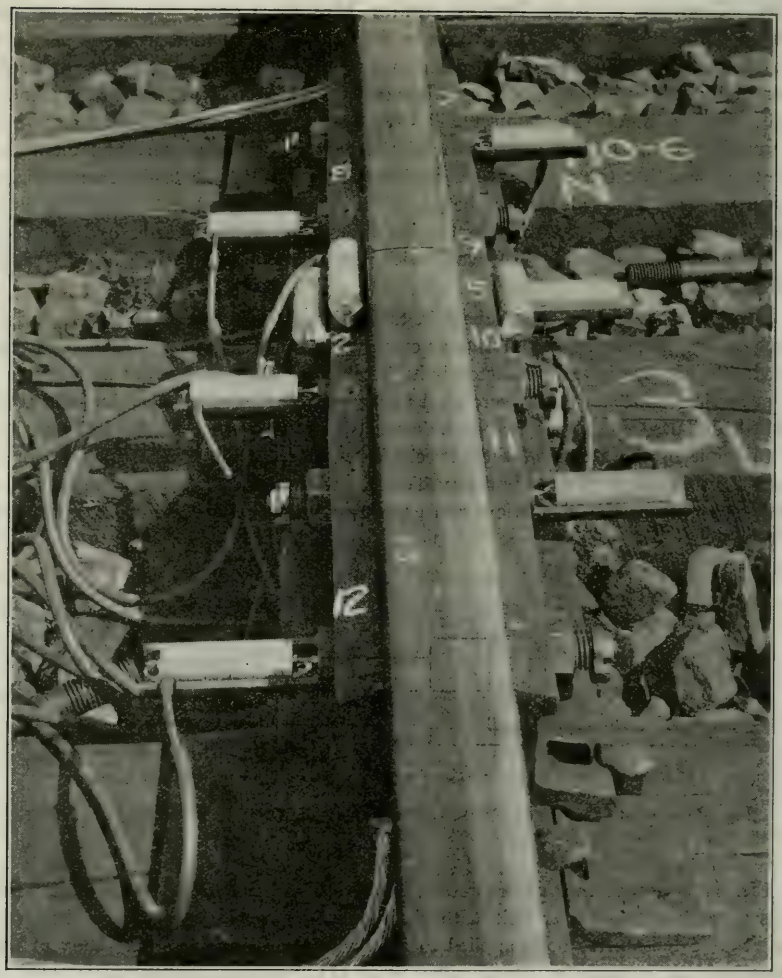


Fig. 46.—View of Six Special Extensometer Bolts Applied to a Rail-Joint in Track.

ing qualities. A case-hardened full-finished nut was used. The bolt was made 1⅛-in. diameter to conform to standard bolt size for the joints tested and was accurately machined to shape and size. A ¼-in. hole was drilled the length of the bolt on its longitudinal axis. At the thread end this ¼-in. hole was enlarged to ½ in. for ⅜ in. and threaded. The bottom of this hole was drilled out to ⅜-in. diameter to fit the head of a $\frac{3}{16}$-in. actuating rod that extends the length of the bolt and screws and locks into the end of the magnetic strain gage which is attached to the movable armature. A closely fitting bushing supports the $\frac{3}{16}$-in. rod at the gage end of the bolt, permitting the rod to slide freely but limiting vibrations in the rod. This rod is fixed with reference to the threaded end of the bolt by screwing a safety set-screw into the ½-in. hole mentioned above so that it bears on the head of the actuating rod. The shelf at the head end of the bolt is semi-circular in cross-section. At its far end a drilled and tapped hole in the supporting shelf takes the stud that carries the part of the magnetic strain gage that is attached to its coils and pole pieces. Thus any change in length of the bolt between the points of attachments of the actuating rod at one end and the far end of the magnetic strain gage causes a shortening of the air gap at one side and a lengthening at the other side of the armature. To give additional support and eliminate vibration a small screw is threaded through the bottom of the shelf and bears lightly against the gage.

For measuring the tension existing in the special extensometer bolts when the joint was not under a wheel load, an 8-in. Berry strain gage was applied between points *A* and *B* of Fig. 45. The gage point *A* is placed near the edge of the shelf at the head end of the bolt. At the threaded end of the extensometer bolt, the safety set-screw that fixes the actuating rod in place was made long enough so that a special washer may be put on and held with a lock nut (shown in the figures). The rim of this washer is cut to show a horizontal axial surface of sufficient area for the strain gage hole *B*. Two similar holes *A′* and *B′* are placed in the same horizontal axial plane as *AB*, one on the shelf and the other on the special washer. The two gage lines thus formed are opposite and equidistant from the longitudinal axis of the bolt. The averaging of the readings on these two gage lines will eliminate the effect of any eccentric loading of the bolt, and their differences will show eccentricity of bearing. This arrangement permits readings of changes in length under static conditions to be taken with an ordinary 8-in. Berry strain gage. The extensometer bolts were calibrated by applying known loads in a testing machine and noting the corresponding changes in the strain gage readings, as well as the movement of the actuating rod. A small key is held temporarily in a keyway common to the special washer and the threaded end of the extensometer bolt while the washer is locked into place, thus ensuring alignment of the horizontal surfaces on which the strain gage readings are taken. The use of the Berry strain gage in the manner described, in place of the magnetic strain gage, decreased the size of the air gap required (equivalent to increasing the sensitivity) and permitted the usual six records to be placed on one film.

The procedure of a test was to place the six special extensometer bolts in a joint with the magnetic strain gages in place but with the armature not yet fixed in position (locking screw loose) and apply a finger-tight tension. The actuating rod was screwed into the gage and locked and the safety set screw tightened, taking the precaution to see that this does not jam the gage which has about ⅛-in. allowance for movement. The special washer was then locked into position as described above. A set of zero readings was taken with the Berry strain gage and the nuts tightened until the proper tension was obtained. The armatures of the magnetic strain gages were then locked in

a central position and the oscillograph adjusted to record the bolt tension changes under moving load. The amount of the total tension was again measured before loosening the nuts.

At the top of Fig. 42 is shown a film record of change in bolt tension for bolt 4 in test (i) at 45 miles per hour. In Fig. 47 and 48 are shown film records of the change in bolt tension in tests (i) and (o) at 45 miles per hour, together with a stress record at one gage line recorded for location purposes. The scale of the change in bolt tension is indicated for each individual bolt record.

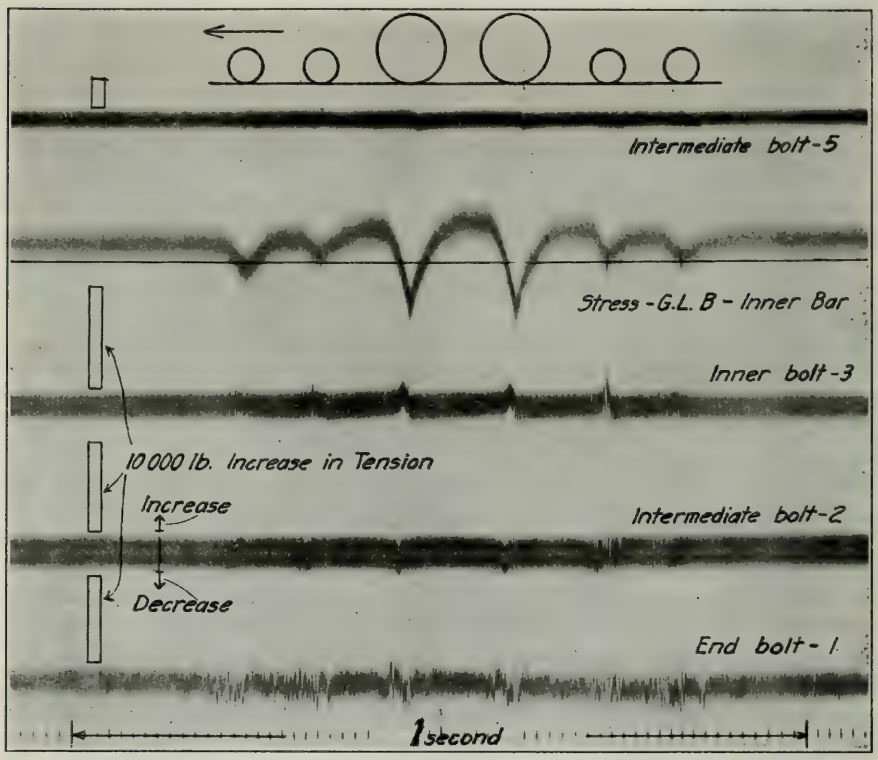


Fig. 47.—Film Records Showing Changes in Bolt Tension and a Concurrent Record of Stress at a Gage Line—Speed 45 Miles Per Hour—Tests at Claymont, Delaware—Test (i) at Joint 3-1.

Use was also made of the extensometer bolts of the Pennsylvania Railroad to indicate the bolt tension changes at one joint location. Previous tests made with these bolts were reported and the bolts described in the Report of the Committee on Rail for 1930*. In those tests telemeters of 2-in. gage length were used to indicate the changes of bolt tension. For the tests herein reported the bolts were adapted to the mounting

* Vol. 31 of the Proceedings of the American Railway Engineering Association (1930), page 1556.

of the 4-in. magnetic strain gage. The mountings were rotated 90 degrees from the position previously used so that the magnetic strain gage was at the side of the bolt. The fit of the moving parts in their bearings was also improved.

Before considering the results of the tests it will be well to state that the changes in tension during the passage of a wheel over a rail-joint were found to be relatively small, frequently less than 500 lb., sometimes 1000 lb. or so, and in some cases 2000 or 3000 lb. At the same time the higher speeds were sometimes accompanied by vibrations of extensometer bolt or of its parts which made the record somewhat less distinct but which could generally be read with fair accuracy and which without doubt represented the

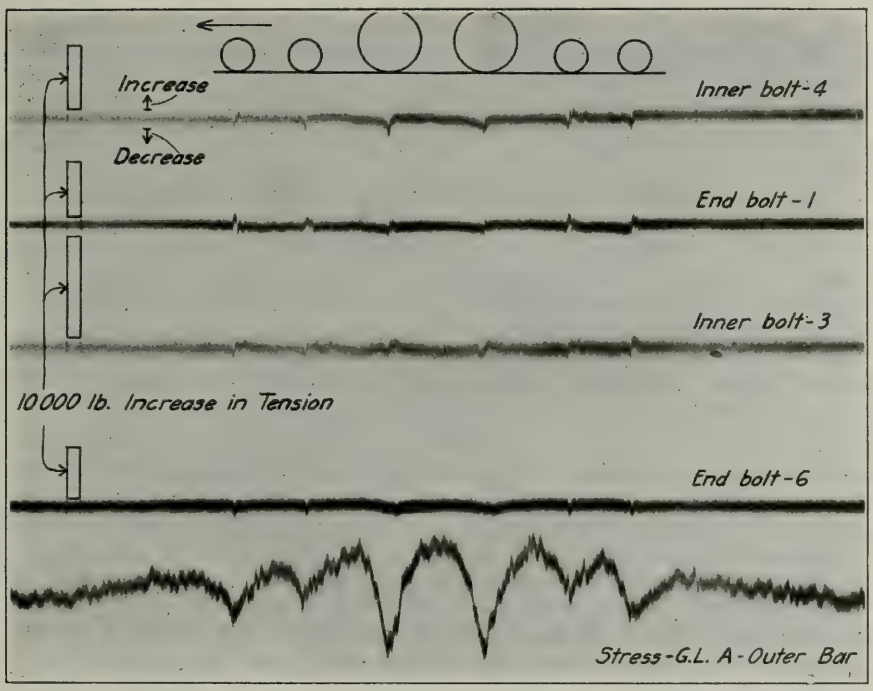


Fig. 48.—Film Records Showing Changes in Bolt Tension and a Concurrent Record of Stress at a Gage Line—Speed 45 Miles Per Hour—Tests at Claymont, Delaware—Test (o) at Joint 9-9.

tension changes. In a few cases vibrations on the record masked the changes in tension, though even here the full amount of the vibratory record would have given only a moderate change, in the worst cases less than 3000 lb. The interpretation of the tests was further complicated by the decreasing tensions from run to run when because of the bars moving toward the rail slightly under the action of the flexure of the bar and rail at each loading after a recent tightening, and by the increasing tensions when the bars moved outward slightly after a recent loosening of bolts without the bars being pried out. Sometimes the horizontal scale was so small that there was uncertainty as to whether the changes on the passage of a wheel were first plus and then minus or first minus and then plus or to what extent the increase and decrease was caused by vibration of rail or

bolt or extensometer. Time was not available before the tests were begun to make better adjustment between the magnetic strain gage and the extensometer bolt and to perfect the technique in a way that would have improved the quality of the records.

With these complications and the chances for instrumental error and the uncertainties in some of the records made, it seems desirable to give an interpretation of the results in a general way rather than to report a tabulation of quantitative results. It is believed that the results as a whole are definite and will serve the purpose of answering most of the questions raised with respect to the effect of speed upon the changes in tension in the bolts.

The tests on changes in bolt tension with the passage of a wheel over a rail-joint were conducted on three of the joints on which stresses in angle bars had been found. The tensions in the bolts with the joints in an unloaded condition were measured immediately before and after the runs for tests (d), (i) and (n) and are given in Table 15. The changes in bolt tension given in the following discussion refer to the increase and decrease in tension as the first driver and the second driver pass directly over the joint.

The records at 5 miles per hour were definite and certain. In joint 4–5 (test (d), tight bolts) the changes in bolt tension during the passage of the two drivers were small, 100 to 300 lb. as read from the record, generally an increase though bolt 4 gave decreases. At 45 miles per hour the increases in the end bolts were 1000 and 1500 lb. and in the others increases or decreases of 500 to 1000 lb. At 70 miles per hour the tension in bolt 1 increased by 1200 lb. and that in bolt 6 by 3000 lb., while that in the other bolts had plus or minus values ranging from 500 to 1000 lb. It is seen that with the increase in speed the magnitude of the changes has increased, but the higher values are not much greater than those found in the laboratory tests.

In test (n) (joint 4–5, with the tension in the bolts completely released, the bars pinched out, and then each bolt set with low tension, perhaps 2000 lb. or less—only one run at each speed), no changes in tension were noted at 5 miles per hour. At 45 miles per hour the increases or decreases in bolts 1 and 5 were about 1500 lb. and the changes in the other bolts were slight or the record was poor. At 70 miles per hour the increase in bolts 1 and 6 was about 1000 and 3000 lb. and in bolt 4 the decrease was about 3000 lb.—the other changes were small except that bolt 5 showed an increase of 3500 lb. under the first driver and no change under the second driver. It is apparent that the lessened restraint of the loosened tension has permitted a greater twisting of the bars.

In test (i) (joint 3–1 with high bolt tension) the changes in tension under the load at 5 miles per hour ranged from zero to 1000 lb. At 45 miles per hour (see Fig. 47 for four bolts of one run) the changes in tension were decreases of 500 to 1500 lb. in bolts 1, 2 and 5, and increases of about the same amount in bolts 3, 4 and 6. For the one run at 70 miles per hour the records that could be read with certainty were about the same, with bolt 5 showing a decrease of 2000 lb.

In test (o) (joint 9–9, with four Pennsylvania extensometer bolts screwed up quite tight, probably an average tension of 30,000 lb.), at 5 miles per hour the decreases in tension in bolts 1 and 6 were 500 lb. and in bolt 4 1000 lb., and no change in bolt 3. At 25 miles per hour the changes were slightly larger. At 45 miles per hour (see Fig. 48 for one run) the decreases in bolts 1 and 6 were 1000 lb. and in bolt 4 2000 lb. At 70 miles per hour the decreases in bolts 1, 4 and 6 were 2000, 2000 and 2500 lb. and the increase in bolt 3 was 1000 lb. It would appear that the bars were still being drawn in toward the rail during the tests.

In test (p), with the same joint 9–9 and the four Pennsylvania Railroad extensometer bolts loosened to a tension estimated at 5000 lb., the record showed little change in tension under load at 5 miles per hour. At 45 miles per hour the tension decreased 1000 and 500 lb. in end bolts and increased 2000 and 3000 lb. in inner bolts. These changes may have been due to a readjustment of the position of the bars with the rail under the reduced tension given by the flexure of the bars and rail upon the application of the loads.

Only small amounts of change in tension were found at the time the joint was between the first and second driver, unless of course the conditions were such that the first driver gave a permanent change in the tension of the bolt.

It may be concluded that the changes in bolt tension as each of the two drivers passes over the joint are not large even at a speed of 70 miles per hour. The change in bolt tension in the 6-bolt joints at 5 miles per hour was small, ranging from zero to perhaps 1000 lb. At 70 miles per hour, with tight bolts (tests (d) and (i)) the changes were about as follows: bolt 1, 2 and 3 1000 lb. or less, bolt 5 1000 and 2000 lb., and bolt 6 3000 lb. or less. With very low bolt tension (test (n)), the changes were somewhat greater. In the 4-bolt joint at 70 miles per hour the decreases were 2500 lb. or less, though probably much of this change was due to the bars working in toward the rail, the runs being made just after the bolts were tightened. In test (p) with lowered bolt tension, the change in end bolts was small and that in inner bolts at 45 miles per hour was an increase of 2000 or 3000 lb., both changes probably being due largely to the readjustment of bars with respect to rail with the lowered tension in the bolts. The sign of the change in tension, whether positive or negative, was generally similar to the signs found in the static tests, if the effect of recent tightening or loosening of bolts and the readjustment of bars and rail is taken into consideration. It may be added that the unsymmetrical form of the angle bars used may be expected to give greater changes in tension at loadings than would be found in bars of symmetrical section for the reason that the greater inclination of the neutral axis in the unsymmetrical section results in greater lateral deflection and a consequently greater lateral movement of the bars inwardly or outwardly, which acts to decrease or increase the bolt tension. The fit between bar and rail, however, must be accepted as having an important influence upon the changes in bolt tension developed under high speeds; the bars in the joints tested all had excellent fit.

The conclusions on the magnitude of the changes in bolt tension are quite contrary to some of the statements of an extreme increase in bolt tension during the passage of a wheel over the rail-joint given in Exhibit A of Appendix G of the Report of the Committee on Rail in Vol. 31 of the Proceedings of the Association. It should be added that the Pennsylvania extensometer bolts in general gave excellent records with the magnetic strain gages. It is evident, too, that the records made with the telemeter, given in the Report of the Committee on Rail just referred to, will give conclusions similar to those stated above if the large vibratory part of the record be recognized as due to vibration and only the tension effect be read.

IV. TESTS OF RAIL-JOINTS ON THE CHESAPEAKE AND OHIO RAILWAY

23. **The Tests of Rail-Joints on the Chesapeake and Ohio Railway.**—In March 1931 the Chesapeake and Ohio Railway in laying new 130-lb. R.E. rail on west-bound track one and a half miles west of Ashland, Kentucky, installed a number of rail-joints with 6-bolt 39-in. joint bars having a heavy section which approaches symmetry with respect to the horizontal geometrical axis. The section of the joint bars is the same as the section of the bars of symmetrical or near-symmetrical type used in the laboratory tests described in Chapter II "Laboratory Tests of Rail Joints" and referred to as the Santa Fe Symmetrical Type Rail-Joint. For convenience the joint bars will be designated as Santa Fe symmetrical bars. The section of the bars is shown in Fig. 3 and its geometrical properties are given in Table 2. The rail-joints were generally laid as supported joints. The track is described in Article 31 "Description of the Track".

This track installation furnished an opportunity to make field tests on rail-joints with heavy bars of a section that is nearly symmetrical with respect to the horizontal geometrical axis. The tests were conducted in September and October 1931. The stretch of track had been subjected to the extremely heavy traffic described in Article 31. Observations were made under static loading on 20 joints for the conditions found in the track to determine the stresses and moments at mid-section of the joint bars and at other sections under static loading. Determinations of deflection, vertical movement between rail and bars, and bolt tension were included in the program.

In the tests on the Pennsylvania Railroad heretofore described, the primary purpose was to determine the action of the rail and rail-joints under moving loads from low to high speeds and the magnetic strain gage gave excellent service, but the complication of the equipment limited the number of rail-joints available from a given position of the equipment and also limited the number and placing of gage lines for determining stress and other information. In the tests on the Chesapeake and Ohio Railway it was desired to make a study of a considerable number of joints in the condition found in the track and to obtain a variety of information on the stresses and deflections of the joints. For these reasons static loading was used and the measurements were made with Berry strain gages, deflection bars, and other instruments applicable to static loading conditions.

24. **The Tests.**—Steel hopper cars of 70 tons capacity were used in the tests. Three loads were used—(1) an unloaded car, (2) a car with a medium load, and (3) a car with a heavy load. Sand was used as a loading material, only the test end of the car being filled. The loads on the truck wheels of the test end of the cars were 26,000 lb. for the light load, 59,500 lb. for the medium load, and 119,800 lb. for the heavy load, which have been called 6500 lb. per wheel for the light load, 15,000 lb. for the medium load, and 30,000 lb. for the heavy load. It was noted that the bolster plates of the loaded end of the cars were always free so that the load on a given wheel may be expected to be fairly constant, and the assumption of equal division of load among the four wheels is not seriously in error, the possible error probably being nearly constant. In making a test on a rail-joint the car was spotted with the end wheel of the loaded end of the car at the desired position with respect to the joint.

The stress measurements were made with the 2-in. Berry strain gage, which has been referred to in Article 6 "The Laboratory Tests of Rail-Joints". A set of readings was taken before the load was placed in position, other sets with the load in place, and

generally a final set when the load had been removed. To compensate for temperature variations during the period of taking readings, a standard reference bar was used and when necessary suitable corrections were applied to the readings; its use also was a helpful warning in case of possible instrumental mishaps. Although the conditions in the field tests were not as favorable to accuracy as those prevailing in the laboratory, it is believed that with the skill used by the observer the errors of observation were not often greater than 600 lb. per sq. in.

Vertical movements between bar and rail were measured with a strain gage of suitable form and gage length. Deflections of rail-joint and rail were measured with a 66-in. bar described in Article 6. Vertical and lateral deflections of the joint bars were measured with a similar bar of correspondingly shorter length. Bolt tension was measured with the new caliper extensometer shown in Fig. 4.

For the more complete tests the time of taking readings on a rail-joint before loading, in loaded condition, and after unloading consumed from two to three hours. The routing of the trains over other tracks of the three-track railroad during most of the day enabled the test work to be carried on thoroughly and expeditiously.

The rail-joints along the stretch of track were numbered consecutively from 1 to 57, the odd numbers on the south rail and the even numbers on the north rail. Tests were made on 20 joints, 14 of them on the north rail and 6 on the south rail. The larger number of joints were chosen on the north rail (outside rail of outside track) because of convenience in the work and to keep away from the heavy traffic on track 2. With the exception of joint 28, which had the rail ends between two ties, the joints were supported joints and the rail ends came very close to the middle of the width of a tie.

Most of the rail-joints tested were taken consecutively along two stretches of track with a view of getting a knowledge of the general run of the joints along the track. Those on the south rail were chosen near certain of the joints on the north rail. The joints tested involved differing conditions—ties close against rail or loose, well fitting or fair fitting bars, bolts tight or loose, bars cocked out of vertical position, etc. Variations in conditions were made—bolts were tightened in some joints, and two pairs of bars were sawed to 26-in. length and re-installed in track.

The tests involved no repetitions of loading. Generally the end wheel of the loaded end of the car was placed directly over the rail ends (mid-section of joint bars). For the general tests the heavy load of 30,000 lb. on each wheel of the loaded end was used. The calculated moment for this load on full rail based on a modulus of elasticity of rail support of 2600 lb. per in. per in. is considered to be 260,000 in.-lb. and this will be used as the basis of comparison. In many of the tests the medium load of 15,000 lb. on each wheel was used and in a few the light load of 6,500 lb. The calculated moments for the medium and light loads are considered to be 130,000 and 56,000 in.-lb., respectively. The heavy wheel load is about 25 per cent higher than that of the capacity load of the 70-ton car—that is, a load somewhat greater than the allowable overweight load. The moment developed in the rail by this wheel load then corresponds fairly well with the moment developed under the front and rear drivers of the Mikado locomotives used by the railroad and is somewhat greater than that under the heaviest freight car load at slow speeds.

The stresses at mid-section were read at gage lines 1a, 2, 3 and 8 on the outer bar and 3 and 8 on the inner bar (see Fig. 3 for position of gage lines). For the six joints on the south rail the position of the wheel flange permitted readings of stresses in gage line 2 of the inner bar to be taken. The flange of a wheel was usually from 0 to $\frac{1}{16}$ in. from the south rail and about $\frac{3}{4}$ in. from the north rail. This evidently resulted

from a difference in the cant of the two rails, that of the south rail at points opposite the joints being generally about 1 in 16 and that of the north rail 1 in 27. It was noticed that similar positions were taken by flanges of wheels of freight trains which stopped along the track.

In addition to the readings at mid-section the stresses with heavy load were also read in seven joints at sections 2, 4, 6 and 12 in. each way from mid-section at gage lines 2 and 8 on the outer bar and sometimes at gage line 3, and at gage lines 2 and 8 on the inner bar where practicable and at 3 and 8 elsewhere.

With the medium and light loads, stresses were read at mid-section with load over mid-section only. These tests were made with a view of showing effect of the observed play in the joint and in the tie support on the development of stress and moment with the application of light, medium and heavy loads.

The heavy load was also placed 6 in. east or west of mid-section and in a few cases at 12, 18, 24 and 36 and 48 in. east of the mid-section. The stresses were read at mid-section. Ordinarily three gage lines were read on both inner and outer bar.

The vertical and lateral deflections of the two joint bars were read for most of the joints. The lateral bending was small. The deflection with the 66-in. bar was also taken at each joint, and the vertical movement between rail and bar at six places along the length of the bar. Thickness gage measurements were also made.

Notes on the general condition of the joints are given in Table 16. Bolt tensions were measured on the three joints in which changes of tension were made during the test. On all other joints an examination was made and the condition of the tightness or looseness of the bolt arrived at by judgment. The results of the tests and the examination of the bolt tension are given in Table 17. The bolts are numbered from west to east. In considering the tightness of the bolts, it should be borne in mind that the examination made might not detect a difference between a bolt tension of say 5000 lb. and a very high tension. Vertical movement between bar and rail on applying the load may indicate whether the bolt tension is low or high.

25. **Stresses and Moments in Joint Bars at Mid-Section and in Rail Opposite with Heavy Load over Mid-Section.**—Table 18 gives the values of the observed stresses at the various gage lines at mid-section of both joint bars with the end wheel of the heavy load directly over mid-section and also at the two edges of the base of the rail opposite the mid-section. For the outer bar the stress at gage line 1a near the highest point of the bar (see Fig. 3 for the position of the gage lines) probably approaches closely to the highest stress developed in the bar. The greatest stress measured was 28,200 lb. per sq. in. in joint 44. It will be noted that the stresses at gage line 1a differ widely from joint to joint, as they do also at the other gage lines. These differences indicate variations in the bending moments developed in the various joints by reason of the stiffness and variability of the rail supports and variable conditions in the joints themselves. There are also differences corresponding to differences in the lateral bending moments and in the amount and direction of the bearing pressure applied to the joint bars. Still another item that needs to be considered carefully is the effect of the bearing pressure of rail on bar at and near mid-section in modifying the relative magnitude of the stresses developed at the gage lines at the upper part of the bars.

In Article 11 "Distribution of Stresses over Vertical Section at and near mid-Length", the effect of the application of the bearing pressure on the top fishing surface of the bar near mid-section has been discussed. It was shown that the observed stress

TABLE 16

Notes on Rail-Joints—Tests on Chesapeake and Ohio Railway at Ashland, Kentucky

Unless otherwise noted, the joint was tested in its original condition with the heavy load only over mid-section and 6 in. east. H, M, and L refer to heavy, medium and light loading.

Joint Number	Series	Date	Remarks
14	88–90	Oct. 3	Low tension in east two bolts.
16	59–61	Oct. 6	
18	56–58	Oct. 1	
20	53–55	Oct. 1	
22	42–52	Oct. 1	Bolt tension measured. H applied at several positions. M at mid-section only.
22	80–87	Oct. 3	Bolts tightened to measured tension shortly before test.
24	35–41	Sept. 30	H, M and L applied.
26	130–137	Oct. 9	H and M applied.
27	138–143	Oct. 9	Four bolts loose. H and M applied.
28	144–149	Oct. 10	Suspended joint. Every bolt loose. Inner bar is in at top and out at bottom. West rail has been slipping with change in temperature. The two joint ties are 12- and 10-in. widths, and the one first east is 14-in. Tie spacing large and variable. H and M applied.
28	237–239	Oct. 14	Before test nuts were wrenched up about 1½ turns to about 15,000 lb.
41	99–104	Oct. 8	Three bolts loose—two low tension. H and M applied.
42	1–6	Sept. 28	H and M applied.
43	105–108	Oct. 8	Outer bar slightly out at bottom. H and M applied.
44	14–20	Sept. 29	Bolt tension measured—mostly low. West rail has slipped in bars. Inner bar out at bottom and bearing on inner part of fishing surface. H, M and L applied.
44	62–67	Oct. 2	Bars sawed to 26 in. and installed with low bolt tension the day before test. Inner bar is slightly out at bottom. Fit and bearing are much the same as in series 14-20.
44	68–70	Oct. 2	Four bolts in 26-in. bars tightened to 10,000 lb. Inner bar only slightly out at bottom.
45	109–110	Oct. 8	
46	7–13	Sept. 28	Bolt tension measured. H, M and L applied.
46	91–95	Oct. 3	Bolts tightened to 11,000 lb.
47	21–27	Sept. 29	H, M and L applied.
47	223–225	Oct. 13	Bars sawed to 26 in. and installed with low bolt tension four hours before test. The low tension was not sufficient to draw the bars properly into place. Outer bar is slightly out at bottom.
47	229–230	Oct. 14	Bars tightened to 15,000 lb. or more and several trains ran over track. Bars had been pulled into proper place and fit well.
48	28–34	Sept. 30	H, M and L applied.
48	226–228	Oct. 13	Bars taken off and reapplied with low bolt tension the day before test. Tension not enough to draw the bars into proper place.
48	231–234	Oct. 14	Bolts tightened to 15,000 lb. or more so that bars fit fairly well. Several trains over before test.
50	111–117	Oct. 9	Inner bar in at top and out at bottom and bearing well toward inside at bottom. H and M applied.
56	118–123	Oct. 9	Generally low bolt tension. H and M applied.
57	124–129	Oct. 9	Tension not more than 1000 lb. except bolt 2. Bars loose.
57	235–236	Oct. 14	Nuts wrenched up 1½ turns making 15,000 lb. tension or more. H and M applied.

TABLE 17

Condition of Bolt Tension in Rail-Joints of Chesapeake and Ohio Railway at Ashland, Kentucky

Unless otherwise stated the description applies to tests made with the original bolt tension found in the joint. L, loose—probably not over 1000 lb. tension; LT, low tension—probably under 5000 lb. tension; T, tight—probably 5000 lb. or above. Measured tension is given in thousands of pounds.

Joint Number	Series	Bolt Number						Remarks
		6	5	4	3	2	1	
14	88–90	LT	T	L	T	T	T	
16	59–61	LT	LT	L	T	T	T	
18	56–58	T	T	T	T	T	T	
20	53–55	T	T	T	T	T	T	
22	42–52	7.2	10.4	3.5	7.1	1.7	8.8	
	80–87	20.4	19.9	20.2	17.9	19.1	24.1	Bolts tightened.
24	35–41	T	T	T	T	T	T	
26	130–137	T	T	T	T	T	T	
27	138–143	L	L	L	LT	LT	L	
28	144–149	L	L	L	L	L	L	Every bolt was loose.
	237–239	T	T	T	T	T	T	Nuts wrenched up 1½ turns to high tension.
41	99–104	L	L	L	LT	LT	T	
42	1–6	T	LT	L	L	LT	L	
43	105–108	L	L	LT	L	LT	T	
44	14–20	3.6	2.2	1.0	1.4	7.2	2.2	
	62–67		2.7	3.0	1.9	6.6		Bars cut to 26 in. and installed with low tension.
	68–70		9.3	10.0	11.4	10.7		Bolts tightened.
45	109–110	T	T	T	T	T	T	
46	7–13	5.1	4.5	1.7	4.6	2.4	6.2	
	91–95	10.2	11.8	12.7	9.3	13.3	12.0	Bolts tightened.
47	21–27	------	------	------	------	------	------	Tension not observed.
	223–228		------	------	------	------		Bars cut to 26 in. New tension not high enough to draw bars into place.
	229–230		T	T	T	T		High bolt tension applied.
48	28–34	------	------	------	------	------	------	
	226–228	------	------	------	------	------	------	Bars taken off and reapplied the day before the test. New tension not high enough to draw bars into proper fit.
	231–234	T	T	T	T	T	T	High bolt tension applied.
50	111–117	L	T	T	T	T	T	
56	118–123	T	LT	LT	LT	LT	LT	
57	124–129	L	L	L	L	LT	L	Bars very loose—tension not much more than 1000 lb. except No. 2 may have had 5000 lb.
	235–236	T	T	T	T	T	T	Nuts wrenched up about 1½ turns—tightened to a high tension.

at gage line 1a (a point close to the upper fishing surface) is considerably greater than the calculated bending or flexural stress necessary to produce a given applied moment, and that the observed stress at gage line 2 (a point well out toward the outside edge of the head of the bar) is somewhat less than the calculated bending stress at this point for the given applied moment, and also that the observed stress at gage line 3 (a point on the side of the head) is considerably less than the calculated bending stress at this point. In the laboratory tests with new 26-in. Santa Fe symmetrical bars, where the loads were applied vertically and without some of the variable conditions found in the track (see Table 5), the average ratios between the moments calculated from the observed stresses at gage lines 1a, 2, and 3 (each in combination with gage line 8) for two pairs of bars and the applied moment were about 1.25, .93, and .83, respectively. For these laboratory tests, then, to obtain the applied load from the observed stresses

TABLE 18

Observed Stresses at Mid-Section of Santa Fe Symmetrical Bars and at Base of Rail Opposite with Heavy Load over Mid-Section—130-lb. R.E. Rail—Tests on Chesapeake and Ohio Railway at Ashland, Kentucky

The stresses are given in thousands of pounds per square inch for a load of 30,000 lb. on each wheel of a four-wheel truck.

Joint Number	Series	Outer Bar				Inner Bar			Base of Rail	
		1a	2	3	8	2	3	8	Outer	Inner
14	89	15.8	13.9	10.3	12.8		8.6	11.9	10.9	6.1
16	60	10.0	9.7	5.5	9.1		5.5	11.4	20.8	—2.4
18	57	15.5	12.8	9.4	15.0		7.5	15.3	12.8	5.2
20	54	13.9	11.7	6.4	14.7		8.0	13.6	13.9	9.1
22	43	23.0	13.3	8.6	17.5		13.3	20.5	8.1	12.7
	81	20.2	12.8	8.3	15.5		15.3	15.0	11.3	10.9
24	36	8.3	8.0	2.5	9.1		7.2	9.7	9.2	7.6
26	131	14.1	13.6	8.6	8.0		7.2	12.2	1.7	13.7
27	140	14.4	17.2	9.7	13.9	11.4	9.4	11.1	4.3	17.7
28	145	25.8	19.1	13.6	18.9		16.6	10.8	11.5	8.9
	238	25.5	18.3	10.0	13.6		15.0	11.4		
41	100	12.2	13.3	8.3	11.4	15.3	11.6	14.7	7.1	9.3
42	2	9.7	10.2	6.4	11.6		3.9	15.5	12.0	9.8
43	107	12.2	8.9	4.7	11.4	9.1	3.9	12.5	4.9	3.7
44	15	28.2	19.4	14.1	19.1		12.8	17.5	9.6	8.4
	63	23.8	14.1	6.1	18.6		12.5	15.2	12.7	8.5
	66	24.6	13.8	8.3	17.4		10.8	18.8	11.6	11.4
	69	15.8	12.0	6.1	13.3		8.0	11.9		
45	110	8.1	3.9	4.2	10.5	6.4	3.0	12.7	6.6	5.8
46	8	7.5	6.9	5.0	12.2		5.3	13.0	11.9	6.1
	92	5.5	8.3	4.2	11.9		5.5	12.8	14.3	8.1
47	22	13.0	11.4	9.1	7.8	7.2	5.0	11.6	6.7	6.9
	224	5.8	5.5	5.0	3.6	4.7	3.0	9.1	9.2	10.6
	230	16.9	10.8	8.0	12.8	13.6	6.9	10.8		
48	29	15.0	12.8	11.9	10.3		14.1	9.7	6.4	6.6
	227	14.1	10.8	6.1	11.9		5.6	6.7	9.0	6.6
	232	21.3	15.3	8.3	13.0		11.4	10.0		
50	112	10.0	7.2	4.2	9.7		7.8	8.6	14.2	15.8
56	119	14.7	13.3	8.3	13.9		13.0	16.1	7.1	7.3
57	126	7.2	8.9	5.0	5.8	10.5	7.2	8.0	5.2	5.6
	236	18.6		11.6	8.9	13.3	7.5	12.2		

the moments calculated from the observed stresses would have to be multiplied by the conversion ratios, .80, 1.07 and 1.20.

With the conditions of loading and of the tie supports at the joints in the track, lateral bending of bars and of the joint as a whole occurs as well as vertical bending. On the assumption that the observed stresses represent the actual flexural stresses, equation (67) (see Article 4) may be used to calculate the vertical bending moment developed in a bar and equation (68) (see article 19) the lateral bending moment developed in the bar for both unsymmetrical and symmetrical sections. In calculating vertical moments, if allowances have to be made for excess or deficiency in observed stresses because of the effects of bearing pressures near mid-section special modifications in the calculations will need to be made in some way.

From the data of the laboratory tests on the Santa Fe symmetrical bars, as noted above, the vertical moments calculated from the observed stresses at gage lines 1a and 8 and 2 and 8 would have to be multiplied by conversion ratios of .80 and 1.07, respectively. Naturally the conversion ratios for joints in track may be expected to differ considerably by reason of difference in fit and tightness and condition of rail support. The ratios between the vertical moments calculated from stresses at 1a and

8 and those calculated from 2 and 8 varied rather widely for the joints tested in track. The average of these ratios for the track was about 1.20, while the corresponding average ratio for the laboratory tests was 1.35. It would appear that the values of the stresses at gage line 2 are relatively more closely representative of the moments than those at gage line 1a, since the stresses at 1a are likely to be affected more largely by the variations in the magnitude and position or the distribution of the bearing pressures than are those at gage line 2. The values of the stresses at gage line 2 when available have therefore been used in the calculation of the vertical moments. It has not been thought best to make an allowance for a deficiency in moment when calculating from gage lines 2 and 8 such as was found from the laboratory tests. Instead, the values of the moments calculated from the stresses at these two gage lines, when available, will be used as the moments developed at mid-section. The variation in the data of the various joints and the differences in the condition of the joints and their supports make it seem well not to go into refinements that may not be justified. At the same time the view may be expressed that the moments developed in these joints, considering the results of the laboratory tests, are on the average probably 5 or even 10 per cent greater than the values calculated from gage lines 2 and 8.

The foregoing discussion refers to the outer bar and to the calculations for the inner bars where gage line 2 was usable. For the inner bars not having readings on gage line 2, a method of conversion ratios for the moments calculated from gage lines 3 and 8 must be provided to overcome the large deficiency in stress at gage line 3. For this symmetrical section the conversion ratio by which the moment in a bar calculated from the observed stresses at gage lines 3 and 8 is to be multiplied will be based on the ratio of the lateral moment calculated from the observed stresses in gage lines 3 and 8 to the vertical moment calculated from the same stresses, $\frac{M_y}{M_x}$. It was found that for the outer bar the ratio $\frac{M_y}{M_x}$ calculated from the stresses observed at gage lines 3 and 8 when plotted against the ratio of the vertical moment calculated from gage lines 2 and 8 and that from 3 and 8 $\frac{M_{2 \text{ and } 8}}{M_{3 \text{ and } 8}}$ with a very few exceptions gave points close to a straight line. This means that the deficiency in the vertical moment by the use of gage line 3 affects the calculated moment in a way similar to the effect on the lateral moment. The lateral moment was calculated by equation (68) (see Article 19). The conversion ratio for use with the inner bar was then taken from a diagram prepared from the data of the outer bar; the vertical moment calculated from gage lines 3 and 8 was multiplied by this conversion ratio and considered the moment developed in the inner bar. It should be stated that the observations indicate that the lateral bending stresses and moments referred to are largely local manifestations, not extending far from the point of application of bearing pressure on the top of bar and that the conversion method used is dependent on an analytical consideration of the local conditions at and near mid-section. Doubtless there are cases where the method has not given a correct result, as was found in a few cases on the outer bar, but on the whole it may be expected that the results are fairly close to the actual moments. It may be noted that the magnitudes of these moments are subject to the same general comment as those of the outer bar—their average is probably low by 5 per cent or more.

In Table 19 are given the vertical moment in joint bars at mid-section with end wheel of the heavy load over mid-section calculated from the observed stresses by the methods just described and also the moment in the rail opposite mid-section. The

joint moment ratio (ratio of moment in joint to the general value of the moment in full rail at places away from the rail-joint, the value of this base being taken as 260,000 in.-lb.) is also given in the table. The rail moment ratio given for the rail opposite a joint is based on the same general value of the general moment in the rail. The joint moment ratios are convenient for making comparisons of moments. It will be seen that the joint moment ratio for the several joints is quite variable, ranging from .40 to .96 for the joints in their original condition.

TABLE 19

Vertical Bending Moments at Mid-Section of Santa Fe Symmetrical Bars and in Rail Opposite with Heavy Load over Mid-Section—Tests on Chesapeake and Ohio Railway at Ashland, Kentucky

Moments are given in thousands of inch-pounds for outer and inner bar and the sum. The base of the moment ratios is 260,000 in.-lb.

Joint Number	Series	Moment in Bars			Joint Moment Ratio	Moment in Rail Opposite	Rail Moment Ratio	J.M.R. / R.M.R.
		Outer Bar	Inner Bar	Sum				
14	89	87	84	171	.66	217	.84	.79
16	60	61	67	128	.49	235	.90	.54
18	57	89	90	179	.69	232	.89	.78
20	54	84	91	175	.67	294	1.13	.59
22	43	98	138	236	.91	266	1.02	.89
	81	91	128	219	.84	282	1.08	.78
24	36	55	70	125	.48	214	.82	.59
26	131	72	78	150	.58	195	.75	.77
27	140	102	73*	175	.67	282	1.08	.62
28	145	123	121	244	.94	260	1.00	.94
	238	105	115	220	.85	---	----	----
41	100	81	97*	178	.68	210	.81	.84
42	2	70	73	143	.55	279	1.07	.51
43	107	65	69*	134	.52	112	.43	1.21
44	15	125	125	250	.96	232	.89	1.08
	63	105	115	220	.85	269	1.04	.82
	66	100	119	219	.84	294	1.13	.74
	69	81	81	162	.62	---	----	----
45	110	45	60*	105	.40	158	.61	.66
46	8	60	71	131	.50	229	.88	.57
	92	64	71	135	.52	288	1.11	.47
47	22	63	60*	123	.47	173	.67	.70
	224	30	43*	73	.28	254	.98	.29
	230	76	80*	156	.60	---	----	----
48	29	76	105	181	.70	167	.64	1.09
	227	73	50	123	.47	198	.76	.62
	232	92	91	183	.70	---	----	----
50	112	54	69	123	.47	384	1.48	.32
56	119	88	120	208	.80	183	.70	1.14
57	126	49	60*	109	.42	136	.52	.81
	236	89	83*	172	.66	---	----	----

*Moment from gage lines 2 and 8 of Inner Bar.

Several sources for the variation in the magnitude of the moment developed in a joint may be noted—spacing of the joint ties as compared with that away from the joint, the fit of the bars to the rail and the play between rail and bars at points along the length of the joint, tension in the bolts, deflection of the joint and adjacent rail, and condition of rail support relative to play between rail and ballast bed from point to point and to stiffness of the support when good bearing has been reached.

For the stretch of track on which tests were made, the spacing of the three joint ties was usually somewhat smaller than that of the ties adjoining and was in most cases fairly uniform, although variation in the width of tie and the spacing probably contributed somewhat to the variations in the moments. The fit of bars and rail and the play between rail and bar was generally satisfactory except in a few joints when the bolt tension had not drawn the bars into place. It was found that except for loose bolts and very low bolt tension these joint bars gave small play and reasonable deflections even without very high tension in the bolts. The variation in the position of the tie and the ballast bed with reference to the rail for adjacent ties and groups of ties (that is, the vertical play between rail and ballast bed) was very marked and evidently was the principal source of the variations in the action of the joints. In Chapter V "Track Depression and Rail Stresses in Tests on the Chesapeake and Ohio Railway", the wide variation in stresses in rail in this track is discussed and the great variability is traced to the variability in the conditions of rail support and the great range in play between rail and ballast bed from point to point along the track. The same variability in rail support exists at and near the joints and will be found to be the principal contributor to the variability in the moments developed in the joints.

Information on bolt tension, play of bars, deflection, and condition of support is not always available. Comments on the results in tests of joints in their original condition on which conditions were not changed in later tests will first be made. Reference may be made to Tables 16, 17, 18 and 19.

Joints 14 and 20 may be considered to have ordinary conditions and normal moments for the condition of the track tested. The low bolt tension in joint 16 may have contributed to the small value of the moment and the joint moment ratio. The depression or "hole" at two joint ties of joint 18 (meaning the large vertical play between rail and ballast bed) may have increased the moment in the bars. The abnormally large moment in joint 22 (joint moment ratio .91) evidently was caused by the "hole" at several ties (see Fig. 64 for play between rail and ballast bed). The deflection in 66 in. was large. In joint 24 the firmer support at two joint ties and their closer spacing, as compared with the support on either side, were the principal sources of the small moment, regardless of the fact that the fit of the bars was excellent. The vertical movement between bar and rail was above average, resulting in more than average deflection in 66 in. for the moment developed, but otherwise the action would be called ordinary. Joint 27 (joint moment ratio .67) had several loose bolts and the deflection in 66 in. was 31 per cent greater than the value proportional to the moment in the joint, as given by the line in Fig. 55.

In joint 41, with three bolts loose and a vertical movement between bar and rail greater than normal and the support of the three joint ties firmer than the adjoining ties each way, the conditions would be favorable to a lower joint moment ratio than is recorded. In joint 42 the conditions of the rail support would tend to make the moment small. The three loose bolts apparently did not affect the fit of the bars except that there was vertical movement between rail and bar of .007 and .009 in. at the rail ends and the deflection in 66 in. was 10 per cent over the average deflection for the moment developed. In joint 43 the two loose bolts at one end had little effect on fit and vertical movement of bars. The support of the joint ties in relation to that of the ties on the east would tend to keep the moment low. The deflection was normal. In joint 45 with tight bolts, the joint ties were on the sloping east side of a deep "hole" (see Fig. 65), and the other truck wheel was in another hole further east, conditions which doubtless were sources for the very low joint moment ratio, .40; the rail moment ratio in

the rail opposite this joint, in a similar situation with respect to the adjacent depression in the support was only .61. Joint 50 had tight bolts and well fitting bars. The deflection in 66 in. was normally proportional to the moment developed in the joint. Although information is not available on the condition of the tie supports, it is probable that variation in support at and near the joint is the source of the low moment. Joint 56, with low bolt tension, had its joint ties situated on the edge of the sloping east side of a very deep "hole" at the west of the joint and the tie supports at the east supporting the other truck wheel were higher, so that it may be concluded that the abnormal supporting conditions were the source of the high moment. In joint 57, loose bolts and large vertical movement of bars with respect to rail together with firmer supports at two of the joint ties combined to produce a very low joint moment ratio.

The effect of change of the bolt tension from a low to a higher amount may be expected to depend upon several circumstances. If the tension is low or the bars loose and this condition has existed for some time, an increase in tension will probably decrease the play or vertical movement between bar and better the fit and thus decrease the deflection in the rail-joint as a whole. Whether this change will result in an increase in the moment developed will depend upon the relative conditions of the tie support at and away from the joint. If the conditions of the tie supports with respect to play and stiffness of support are fairly uniform, the tightening of the bolts from a loose condition may be expected to increase the moment. If the condition of the supports at the joint ties govern, there may be little change in moment. For bars of symmetrical section, a low bolt tension which holds the bars well in position may not be expected to produce much immediate change in the moment developed. Some of these comments are illustrated in joints tested with both original and increased bolt tension.

In a few joints the bolts were tightened before a second test was made. In joint 22 the original bolt tension ranged from 1700 to 10,400 lb., altogether not a very low bolt tension for the symmetrical form of bar and not one that should give low moments. When the bolt tension was increased to about 20,000 lb. the sum of the vertical movements between bar and rail remained nearly the same, but the deflection in 66 in. decreased in the same proportion as the joint moment ratio, which changed from .91 to .84. The original bolt tension in joint 46 ranged from 1700 to 6200 lb., a low tension, but the bars were held in place. Tightening the bolts to 10,000 lb. reduced both vertical movement and deflection very slightly and the moment increased only slightly. This joint was at the edge of a deep "hole". In joint 57 the bars were quite loose and the bolts did not appear to have more than 1000 lb. tension except bolt 2 which may have had 5000 lb. The position of the bars was readily moved with a hammer. The rail-joint received considerable support at the joint ties. Wrenching the nuts to a high tension had the effect of increasing the joint moment ratio from .42 to .66.

After the test of joint 48 in its original condition, the bars were taken off and again put on a day before the tests of series 226-228 and 231-234 were made. The bars were purposely applied in a careless way and the bolts given a low tension, which did not draw the bars up to the original place. The joint moment ratio was reduced from .70 in the original condition to .47. Upon applying a tension high enough to draw the bars into proper fit the joint moment ratio was found to be again .70.

In two joints the bars were sawed off to 26 in. and placed back in track with four bolts having about the same low tension in each bolt as the bolts in the 39-in. bars had originally, and after a test the bolts were tightened to a higher tension and the joint again tested. In both cases, the pull-up and push-down tests show that the middle joint tie gave inadequate support. In the original condition of joint 44, for some unknown

cause an extremely high moment was developed (joint moment ratio .96). In series 63 and 66 with low bolt tension and bars not drawn closely into position and tested first with the end wheel over the joint and then with the other wheel of the truck over it, the joint moment ratio for the 26-in. joint fell to .85. When the bolt tension was tightened to about 10,000 lb. the resulting joint moment ratio was .62. In this connection it may be noted that the observed vertical deflection in the bars for 25 in. was smaller for the last test than for the others. For the original condition of joint 47 (with bolt tension not observed, but with vertical movement between rail and bar extremely small) the joint moment ratio was .47. When the 26-in. joint was tested with low bolt tension, not high enough to have drawn the bars in to proper position, the joint moment ratio was very low, .28. Upon applying a high tension in the bolts and overcoming the play of the bars, the joint moment ratio rose to .60. These few tests are so limited and the conditions are so unrepresentative that the results should not be used in comparing the action of long and short bars.

In joint 28, the rail ends came between ties (suspended joint) at the side of a "hole", all bolts were loose, and the vertical play of the bars was considerable. The high value of the joint moment ratio (.94) corresponds to the large value of the deflection in 66 in. When the bolts were given a high tension the joint moment ratio became .85. The conditions of this joint were abnormal.

In Table 19 are also given the values of the moments developed in the rail at a point directly opposite a rail-joint. These magnitudes vary greatly from point to point; the variation in moments and in play between rail and ballast bed are discussed in the next chapter. The moment opposite joint 50 (384,000 in.-lb.) is extremely high. In the column marked "Rail Moment Ratio" the ratio of the moment developed in the rail at the section opposite a rail-joint to the general value of the moment developed in the rail by the heavy load (taken as 260,000 in.-lb.) is given. In the last column (marked $\frac{J.M.R.}{R.M.R.}$) the quotient of the joint moment ratio divided by the rail moment ratio is given. The average of these quotients or ratios is about .75. With a few exceptions, which are generally explainable by the conditions of the joints and the rail support, the ratios are reasonably concordant. The ratio .75 may be taken to represent the moment developed in the rail-joint in terms of that in the rail opposite it.

It may be concluded that the principal source of the variability in the magnitude of the moment developed in the joint bars and the consequent joint moment ratio lies in the variability of the rail support from tie to tie and from a group of two or three ties to an adjacent group, as indicated by the difference found in the values of the push-down and pull-up tests, in ways that are similar to the sources of the variability in stresses in rail that will be discussed in the next chapter. It is reasonably certain that with more nearly uniform rail support the average joint moment ratio would be higher and would more nearly approach the moment ratio of the rail opposite it (as would be desirable) than was found to be the case. The fit of bars and the play between rail and bar was generally satisfactory except in a few joints when the bolt tension was not sufficient to have drawn the bars into place. The deflection of the rail-joint in 66 in. was reasonably good considering the variability in the rail support. With a tension of 5000 lb. or more maintained in each of the six bolts it is evident that satisfactory action is developed in well fitting symmetrical bars that have been drawn into proper place. It seems evident that with more nearly uniform supports the average relation of the joint moment to the moment in rail opposite would be higher than the average value recorded, which was .75.

For the symmetrical form of bar used in this track, the stresses did not differ greatly from values proportional to the distance of the gage line from the horizontal geometrical axis, except as influenced by the general lateral bending of a joint due to conditions of the rail support. Such variations as were found rarely reduced the effective stiffness of the bar in a vertical direction more than 15 per cent, as found by a consideration of the inclination of the neutral axis obtained from the measured stresses.

26. **Stresses and Moments in Joint Bars at Mid-Section and in Rail Opposite with Heavy, Medium and Light Loads over Mid-Section.**—The tests with heavy, medium and light loads show that for the track tested the stresses and moments in joint bars and in the rail opposite are not generally directly proportional to the applied load as would be the case if the modulus of elasticity of rail support were constant for the different loads and there were no play between rail and ballast bed or if this play were uniform from tie to tie. For uniform conditions the moments developed with the wheel loads of 30,000, 15,000 and 6500 lb. may be considered to be 260,000, 130,000 and 56,000 in.-lb., respectively—or proportional to 1.00, .50 and .22. It has been found that the smaller loads more frequently give relatively higher moments than are indicated by the above values.

Table 20 records the observed stresses in thousands of pounds per square inch at the various gage lines in the two bars of the rail-joints and at the outer and inner edges of the base of the rail opposite for the heavy, medium and light loads. It is apparent that the stresses at a given gage line are not generally directly proportional to the load. It is also apparent that the relative values of the stresses at gage lines 2 or 3 and 8 are frequently quite diverse for two loads and that the relative values in the two bars vary considerably. It is evident that there are lateral bending and twisting actions in the two bars and in the joint as a whole. Some part of these differences may be caused by differences in lateral thrusts caused by the load and by the position of the bearing of the wheels on the rails, though very little difference in the position of the wheel bearing on the rail was observable. A large part, however, is due to variability and eccentricity in the support of the rail on the tie-plate and tie and the support of the tie on the ballast bed both longitudinally and laterally—all combining to cause variations in the amount and position of the upward reaction upon the rail at consecutive ties when the load is applied and to produce variable lateral bending and twisting when the several loads are applied. Similarly, the stresses in the two edges of the base of rail opposite a rail-joint are relatively quite diverse in magnitude with respect to the weight of the heavy load and the medium load for the various locations at which tests were made. For example, at a point opposite joint 24 the stresses at outer edge and inner edge of base of rail are 9200 and 7600 lb. per sq. in. for the heavy load and 8400 and 3000 lb. per sq. in. for the medium load, while opposite joint 27 they are 4300 and 17,700 lb. per sq. in. for the heavy load and 1500 and 16,900 lb. per sq. in. for the medium load. It should be borne in mind that these differences refer to stresses and that the corresponding moments will not have the same relations.

The data of the stresses developed in the joint bars with the medium and light loads indicated that the average conversion ratio (ratio of moment calculated from gage line 2 and 8 to that from 3 and 8, referred to in the preceding article) as determined from the outer bar would not vary far from unity, and so the moments for the inner bar calculated from the stresses at gage line 3 and 8 were used without the use of a conversion ratio in the calculation of the moment at mid-section when the stress at gage

TABLE 20

Observed Stresses at Mid-Section of Santa Fe Symmetrical Bars and at Base of Rail Opposite with Heavy, Medium and Light Loads over Mid-Section—130-lb. R.E. Rail—Tests on Chesapeake and Ohio Railway at Ashland, Kentucky

The stresses are given in thousands of pounds per square inch for a load of 30,000, 15,000 and 6,500 lb. on each wheel of a four-wheel truck, designated as H, M, and L, respectively.

Joint Number	Series	Load	Outer Bar				Inner Bar			Base of Rail	
			1a	2	3	8	2	3	8	Outer	Inner
22	43	H	23.0	13.3	8.6	17.5		13.3	20.5	8.1	12.7
	51	M	14.1	6.9	5.5	12.2		8.9	15.5	4.6	12.4
24	36	H	8.3	8.0	2.5	9.1		7.2	9.7	9.2	7.6
	39	M	5.8	7.5	2.5	6.9		4.4	7.2	8.4	3.0
	40	L	2.5	3.6	0.6	4.4		1.9	5.0	6.2	3.2
26	131	H	14.1	13.6	8.6	8.0		7.2	12.2	1.7	13.7
	136	M	11.9	10.3	6.7	5.3		5.5	6.9	2.1	6.9
27	140	H	14.4	17.2	9.7	13.9	11.4	9.4	11.1	4.3	17.7
	139	M	9.2	9.2	5.3	10.0	7.2	5.8	5.8	1.5	16.9
28	145	H	25.8	19.1	13.6	18.9		16.6	10.8	11.5	8.9
	148	M	15.3	12.5	9.1	9.1		10.0	6.1	4.4	5.0
41	100	H	12.2	13.3	8.3	11.4	15.3	11.6	14.7	7.1	9.3
	103	M	10.0	11.1	8.0	3.9	10.3	7.5	8.6	3.7	5.1
42	2	H	9.7	10.2	6.4	11.6		3.9	15.5	12.0	9.8
	5	M	6.1	4.2	4.4	9.4		1.9	10.3	8.5	5.9
43	107	H	12.2	8.9	4.7	11.4	9.1	3.9	12.5	4.9	3.7
	106	M	7.8	6.6	2.2	5.8		3.6	6.4	4.6	4.0
44	15	H	28.2	19.4	14.1	19.1		12.8	17.5	9.6	8.4
	18	M	16.9	14.7	11.4	13.0		6.1	13.0	6.8	4.8
	19	L	10.0	6.9	6.6	7.8		3.0	7.2	5.2	2.8
46	8	H	7.5	6.9	5.0	12.2		5.3	13.0	11.9	6.1
	11	M	5.5	6.9	5.0	10.0		3.9	8.9	6.0	1.6
	12	L	3.0	4.7	4.4	6.9		2.2	4.4	1.8	3.2
47	22	H	13.0	11.4	9.1	7.8	7.2	5.0	11.6	6.7	6.9
	25	M	6.6	6.4	5.0	4.7	1.9	1.7	5.3	6.1	6.3
	26	L	4.2	2.8	1.9	3.6		1.7	3.3	2.4	3.2
48	29	H	15.0	12.8	11.9	10.3		14.1	9.7	6.4	6.6
	32	M	8.6	7.8	6.4	8.0		10.5	6.1	3.0	3.0
	33	L	5.3	4.7	2.5	4.2		7.7	1.1	0	0
50	112	H	10.0	7.2	4.2	9.7		7.8	8.6	14.2	15.8
	116	M	8.0	3.9	2.8	5.8		4.7	5.3	7.4	7.4
56	119	H	14.7	13.3	8.3	13.9		13.0	16.1	7.1	7.3
	122	M	8.9	7.2	5.5	8.3		10.8	11.9	2.4	2.6
57	126	H	7.2	8.9	5.0	5.8	10.5	7.2	8.0	5.2	5.6
	125	M	2.5	6.9	3.0	3.0	6.9	3.9	5.5	3.1	1.5

line 2 was not available. In Fig. 49 the moments at mid-section for two bars are plotted for the heavy and medium loads and also for the light loads when a test was made. In Fig. 50 the moments in the rail opposite the joint are similarly shown.

It will be noted in Fig. 50 that in a part of the tests on the rail opposite a joint the prolongation of the line joining the points for heavy and medium load or medium and light load would pass through or near the origin of coordinates so that for these tests the moment developed with the loads may be said to be directly proportional to the load. In others, the prolonged line would pass well above the origin, but in such cases the increase in moment above the lighter load is fairly near being proportional to the increase in load. It is evident that the larger development of moment with a small load is due to play between rail and ballast bed and that the rail bearings at points well away from the given section take proportionally greater reactions (even though small) than those near the section and thus have a greater than normal effect on the moment

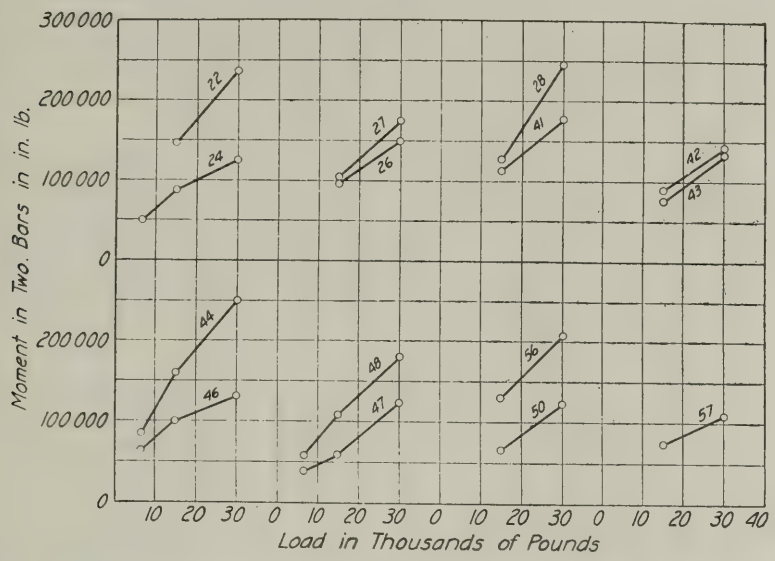


Fig. 49.—Vertical Bending Moment in Two Joint Bars at Mid-Section for Fifteen Rail-Joints—Tests on Chesapeake and Ohio Railway.

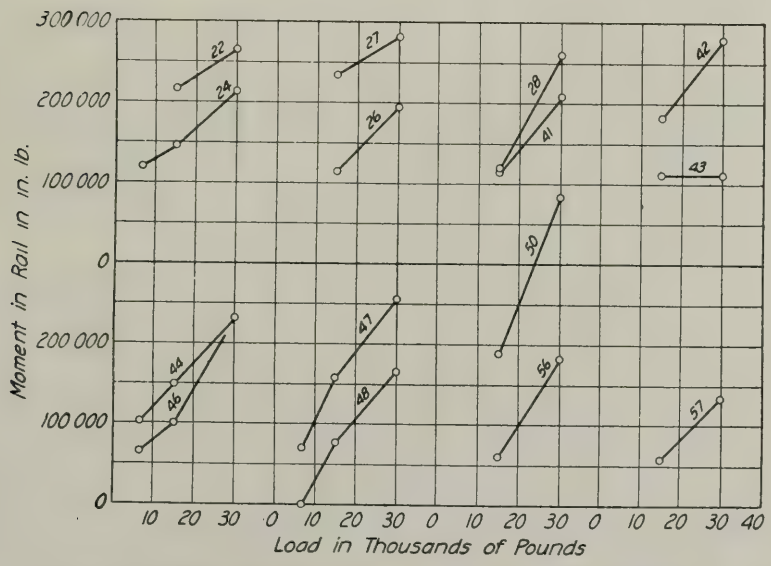


Fig. 50.—Vertical Bending Moment in Rail opposite a Numbered Rail-Joint—Tests on Chesapeake and Ohio Railway.

developed. After fair bearings are obtained on all the ties the further moment developed may be expected to be proportional to the increase in load. The conditions opposite joint 43 are apparently abnormal or one set of readings contains errors; the moments are the same for medium and heavy load. It seems possible that the location of the other wheel on the same rail over a "hole" (see Fig. 65) may have developed differing negative moments under the rear wheel which gave this modification.

The moments in the joint bars plotted in Fig. 49 for the two or three loads show similar results. Generally the smaller load produces a larger moment proportionally than the next higher load, but the rate of increase in moment with increase in load is fairly proportional to increase of load. The same explanation holds for joints as for the full rail. Variations in play between rail and ballast bed more greatly affect the development of moment with the application of the first part of a load. Similar results were found with earlier tests. For the variation of depression at rail-joints with several loads see Fig. 86 of the Fifth Progress Report.

27. **Moments in Joint Bars at Mid-Section and in Rail Opposite with Heavy Load at Various Positions with Respect to the Rail-Joint.**—Stresses were observed at mid-section of the joint bars and in the rail opposite when the end wheel of the heavy load was over mid-section and also when it had been moved from point to point away from mid-section. The stresses were read at mid-section and in the rail opposite when an end wheel rested at 6 in. east of mid-section (retreating), and for part of the joints with wheel 24 in. away, and in a few with wheel at other positions, such as 12, 36, and 48 in. As would be expected from the conditions of the rail supports, the several positions of the load gave quite diverse lateral bending and twisting effects at mid-section of the different joints as well as varying vertical bending moments. These marked variations were found both in the rail opposite the joint and in the joint bars of the several rail-joints tested.

In Fig. 51 are plotted the vertical moments at mid-section calculated from the observed stresses for positions of the end wheel at various distances from mid-section for 8 joints and for the rail opposite, and likewise the corresponding moments in the full rail directly opposite the joint, thus forming experimental influence lines. A curve is also plotted from analytical considerations showing calculated values in the full rail as a wheel would retreat away from mid-section, based on a moment of 260,000 in.-lb. with a wheel over mid-section and a modulus u of 2600, giving the analytical influence line. Much of the variation from the analytical line is doubtless due to the variations in rail support, as well as to the differing conditions in the joints themselves.

In Fig. 52 the analytical value for the moment in the rail opposite the joint as a wheel moves away from mid-section is plotted considering the value of the moment for wheel load directly opposite the joint as 1.00—the moment becomes 0 when the end wheel is 24 in. from the given section. The average values of the moment in rail calculated from the stresses observed in the rail opposite a joint are plotted in the diagram for several positions of the load, as are also the moments found at mid-section of the joint bars. For some of the load positions, especially those at a distance from the section for the rail and joint considered, values were obtained at only a few joints, but the line drawn for the joint may be taken as representative of a composite influence line for the moment at mid-section of the joint bars. Similarly, the line for the rail section is representative of the influence line for the full rail. The values used in plotting the influence line for the rail did not include four locations for which the moment in the rail section with the wheel 6 in. away from the given section was considerably larger than when the wheel was directly over the section and for which the

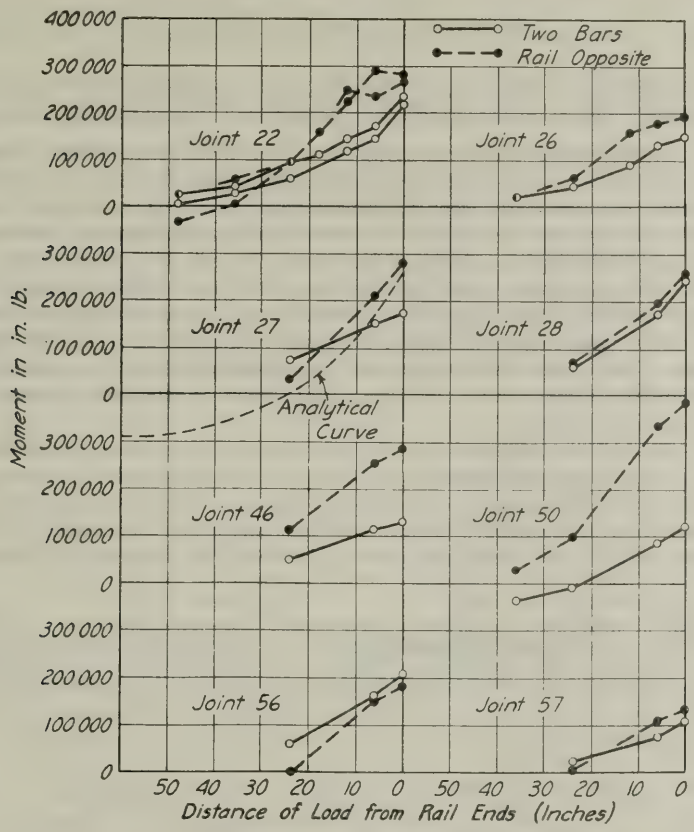


Fig. 51.—Vertical Bending Moment in Two Joint Bars at Mid-Section as the Wheel is Moved from Point to Point Away from the Rail Ends and Corresponding Moment in Rail Opposite—Tests on Chesapeake and Ohio Railway.

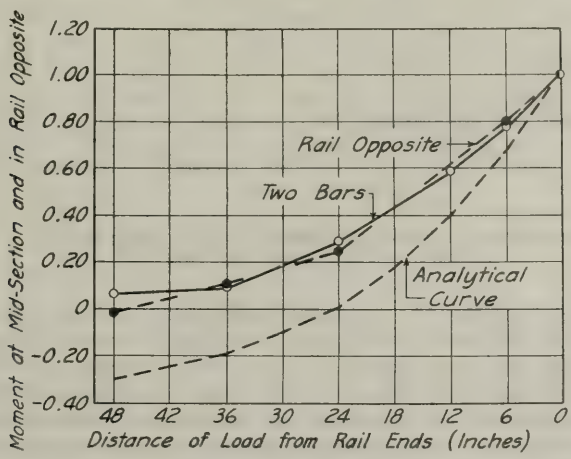


Fig. 52.—Composite Values of Bending Moments in Two Bars at Mid-Section as the Wheel is Moved from Point to Point Away from the Rail Ends and Corresponding Moment in Rail Opposite, Each in Terms of the Moment with Wheel at Rail Ends and Opposite—Chesapeake and Ohio Railway.

resulting influence line closely approached the curve of analytical values—an abnormal result doubtless due to peculiar or defective conditions of the rail support at ties near by.

28. **Stresses and Moments along the Joint Bars with Heavy Load over Mid-Section.**—For seven joints stresses were read at gage lines 2, 3 and 8 at sections 2, 4, 6 and 12 in. each way from mid-section with one wheel of the heavy load over mid-section, and in some of these joints similar readings were made for different conditions of bolt tension and for shortened joint bars. In several of these tests the stresses and the resulting moments along the bars were small, and, besides, in some cases the varying lateral bending in the rail and joints and the influence of observational errors on the results obscured the distribution of moment along the bars. In most joints the magnitude of the stresses in the upper and lower portions of the bars was nearly proportional to the distance from a horizontal axis, except as modified by lateral bending of the joints as a whole.

The shape of the moment distribution curve along the bar varied, depending on the fit, the vertical movement between bar and rail, and the tightness or looseness of the bolts. With good fit, little play, and medium or high bolt tension, the moment distribution curve showed a pointed or peaked condition throughout the middle of its length. Even with medium low tension and good fit the curve was pointed at the middle, as is

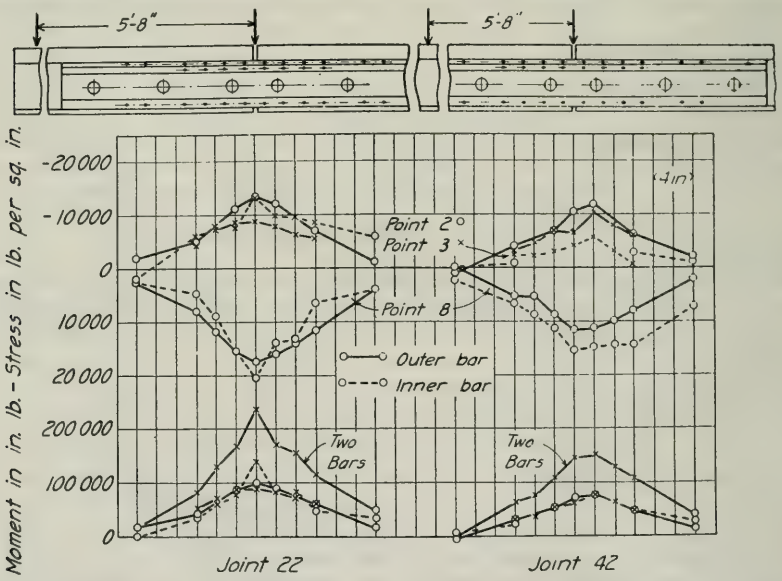


Fig. 53.—Distribution of Stress and Moment along Joint Bars in Joints 22 and 42 —Tests on Chesapeake and Ohio Railway.

shown for joint 22 in Fig. 53. In joint 42, with three loose bolts and quite a vertical movement at the rail ends the curve shown in the figure is rounding through the middle of the length and the bearing pressure of rail on bar is evidently spread over some little distance from the rail ends. The data of other joints having play and loose bolts show a flattening of the peak or a rounding. In joints having looseness of bolts and play, tightening of bolts gave a more pointed moment diagram. When the fit was excellent with low bolt tension there was little change in the shape of the moment diagram with

bolts tightened. With good fit and small play, for joints having a gage line at 12 in. from mid-section, the magnitude of the stresses was found to be small at 12 in. from mid-length.

The shape of the moment diagrams obtained indicated that with good fit and moderate or high bolt tension the centroids of the reaction forces fell at say 2 to 6 in. either way from mid-section for the interior reactions and 12 to 16 in. for the end reactions. The shape of the moment diagrams of three joints with low bolt tension or loose bolts indicates a single reaction on each half of the bar located about 12 in. from mid-section. In general, the moment developed at 12 in. from middle is relatively small. The stress data for the two pairs of bars cut to a length of 26 in. are not entirely consistent and do not extend beyond 6 in. from mid-length, but the moment developed at 6 in. from middle bears about the same proportion to the moment at mid-section for both long and short bars in the two joints used for this purpose. As a whole it may be concluded that nothing in the field tests indicates that the findings of the laboratory tests are not applicable to the conditions of the field.

29. **Vertical Play between Rail and Joint Bar and Deflection of Rail-Joint in 66 Inches.**—The measurement of vertical movement between rail and bar in a rail-joint upon the application of both heavy and light loads at mid-length of joint was made with a special Berry strain gage on 16 joints in their original condition and in some cases with modified conditions such as changed bolt tension and shortened length of bar. Measurement was made between the side of each bar and the side of the rail head near the ends of the bar and near the ends of the two rails and at two intermediate places near the quarter points of the length of the bars. Except where the bolts were loose, the magnitude of the vertical movement was generally small, ranging from 0 to .001 in. or sometimes to .002 in., although in some cases the movement at one or both rail ends was .005 in. or even more. At the middle of the length of the bars any vertical movement found was negative, a closing between head of rail and bar. At the ends of the bars a movement between rail head and bar generally was an increase and is called positive, though in a very few instances the distance decreased. At the intermediate points of measurement, any movements were small, except for the joints having considerable looseness, in which case the value was intermediate in amount between the values at middle and end with signs considered.

In Fig. 54 the vertical movements between head of rail and bar are plotted for joints with tight bolts, joints with loose bolts, joints with bolts tightened above the original condition and 26-in. bars not pulled into place and also with high bolt tension. Reference may be made to Tables 16 and 17 for the condition of the joints. In Fig. 54 bolt 1 is at the right end of each bar and 6 at the left end.

Of the joints with moderate to high bolt tension, joint 22 with the original moderate tension (series 43) gave little vertical movement for both heavy and medium load, 0, 0, 0, and —.001 in. for the four measurements at the middle of the two bars and —.001 to +.002 in. at the ends. A .005 in. thickness gage was inserted between the bottom of the outer bar and the fishing surface of the rail from the end of the rail west for 6 in., both when unloaded and when loaded. At all other places along the two bars the thickness gage could not be inserted. It is seen that loading the joint changed the relative position of bar and rail very little. With the bolt tension increased to about 20,000 lb. (series 81) the thickness gage with the joint unloaded and loaded was inserted for a distance of only ½ in. instead of 6 in., and the vertical movements at the ends upon loading were a little smaller and those at the middle were not

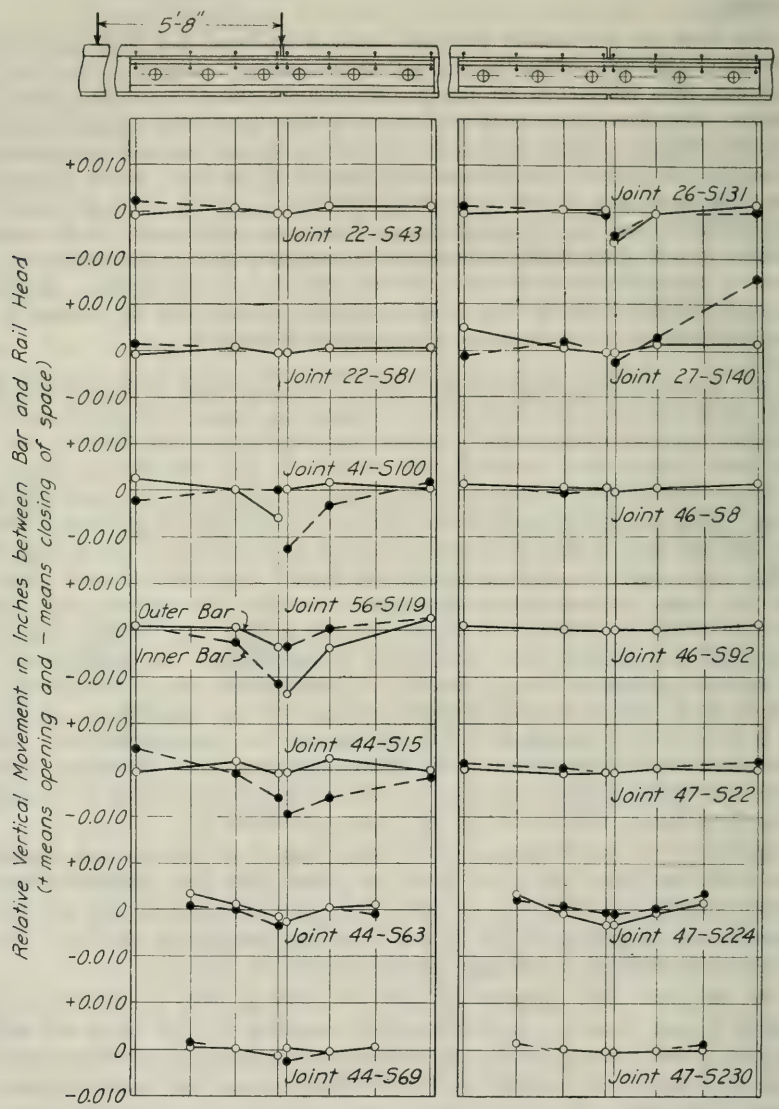


Fig. 54.—Vertical Movement between Rail and Joint Bars—Chesapeake and Ohio Railway.

changed upon applying load. In the test of joint 24 (all bolts tight—thickness gage not insertable anywhere) the measurements indicated no movements. For joint 26 (tight bolts) the measurements included seven at 0 and three at +.001 in., but the two at the end of one rail were —.007 and —.005 in. and thickness gages could be inserted beneath the bars at these places only when load was applied. Joint 45 (tight bolts) showed 0, 0, 0 and —.002 in. at middle and slight or no movement elsewhere; thickness gage could not be inserted at any place, either when unloaded or loaded. Joint 47 (series 22; presumably tight bolts) showed no movement except a slight one at the end of the inner bar. Joint 50 (with tight bolts, and no gage insertion, either unloaded or loaded) gave 0, 0, —.001 and —.001 in. at the middle and slight movement elsewhere. The above comments apply to results with both heavy and medium loads. It is apparent that the bars generally had good fit and that the movement between rail and bar was small except at one rail end.

For the tests of joints with low tension, one rail in joint 44 (series 15) apparently slipped in the bars from temperature change during the test between zero reading and reading with the heavy and the medium loads so that the values of vertical movement in the joint for both loads are evidently unreliable. From the tests with the shortened bars (series 63), however, it is probable that the vertical movements in the joint in its original condition were small. In joint 46 with bolt tensions from 2000 to 6000 lb. (series 8) the vertical movements for heavy and medium loads were zero or very small all along the bars, and the low load gave slightly smaller movements. Before load the gage was inserted from ½ in. east of the end of the east rail for 8 in. eastward but not upon loading. Joint 56 with low bolt tension gave larger vertical movements at the middle (—.003 to —.014 in.) and fairly small values at the ends (+.001 to +.003 in.); the medium load gave nearly the same results. The thickness gage was inserted at top or bottom of both bars through the middle 20 in. of the length of the bars. Except for the middle portion of joint 56, where thickness gage measurement showed considerable play and lack of fit, the low bolt tension of these joints gave only inconsequential vertical movement.

In the joints having three loose bolts or more the amount of the vertical movement varied but the values were greater than were generally found in the joints having tighter bolts. Joint 27 with west inner and west intermediate bolts having low tension and the other four bolts loose showed minor vertical movement at the middle of the bars and large movement at an end of both bars; the thickness gage measurements showed corresponding conditions. Joint 28 with all bolts loose also showed minor movement at the middle and large movement at the ends of a bar. The thickness gage was inserted at the ends of both bars at top both when unloaded and loaded and also at the top of the inner bar west for 8 in. from the middle; at the bottom under load only the thickness gage was inserted for 2 in. west of middle for outer bar and for 6 in. west of middle for inner bar. In joint 41 with three bolts loose and two with low tension, the end of one rail came closer to the outer bar by —.006 in. and the end of the other rail closer to the inner bar by —.013 in., but the largest movement elsewhere was .003 in. At the bottom of the inner bar under load only the thickness gage was inserted for 5 in. west of the middle, the maximum space at west middle being .015 in. In joint 57 with five bolts loose and one having low tension the movement at end of one rail was —.007 and —.005 in. and that at the east end of the bars was +.005 in. and +.018 in.—the other movements were moderate. At top of both bars at east end (both loaded and unloaded) the thickness gage was freely inserted for some distance, and at bottom of both bars west from middle for 7 in. In joint 43 with three bolts loose and two with

low tension and one tight the movements were small except that the east end with the loose bolts had a movement of +.003 in. at the outer bar and —.003 in. at the inner bar. The thickness gage showed good fit.

It is apparent that the form of this joint bar and its fit were conducive to keeping the vertical movements between rail and bar small or moderate when the bolts were tight or even when there was low tension. For joints having three or more bolts loose the movements were not very large in any joint. The small movement in the joint having two bolts loose and three bolts with low tension and the absence of very large movement in any of the joints also suggests the advantages of the 6-bolt joint regardless of the length of the bars.

As has been suggested elsewhere, the effect of tightening bolts in these joints depended on several different conditions—in some the vertical movement between rail and bar was decreased, in others no marked difference was found. Increasing the bolt tension in joint 22 to 20,000 lb. made little difference in the vertical movements, for the fit originally was good and the measured movement was small. In joint 46, changing the original tension of between 2000 and 6000 lb. to 12,000 lb. produced almost no change in the vertical movement. The same thickness gage insertions could be made for both conditions. For bars of joint 48 taken off and reapplied with a bolt tension insufficient to draw the bars into proper place with respect to the rail the vertical movement was hardly greater than that of the bars in their original position, and a tightening of the bolts acted to make only a small decrease in the movement. The original fit as shown by the thickness gage was fair, becoming very poor when the bars were reapplied with low bolt tension, and gaining good fit when bolts were tightened.

No great difference in fit was found when the 39-in. bars were sawed to 26 in. and reapplied in the same joint. In joint 44 in its original condition (series 15; bolt tension 1000 to 7000 lb.) the vertical movement at the middle of the inner bar was —.006 and —.009 in. With bolt tension of 2000 to 6000 lb. in the four bolts of the shortened bars (series 63) the movement of the inner bar at middle was decreased to .003 and .002 in., and with bolt tension of about 10,000 lb. (series 69) only small changes in these vertical movements were found. Thickness gage insertion indicated fairly poor fit of bars under the first condition and good fit under the second and third. When the shortened bars of joint 47 were installed with low tension (series 224) the vertical movement at the middle and ends increased somewhat over that of the original joint, and when high bolt tension was applied (series 230) the measurement was approximately the same as the small vertical movement observed in the original 39-in. bars. In the original 39-in. joint the thickness gage was inserted at top of outer bar for 5 in. east of middle, both unloaded and loaded. With the 26-in. bars applied with low bolt tension (not high enough to draw the bars properly into place), thickness gage insertion was slight at ends and middle of bars. With tightened bolts the fit was improved. It is apparent that for these two joints little difference in fit and in vertical movement for similar conditions of bolt tension was found between the lengths of 39 and 26 in. installed at the same point in track.

With reference to the effect of the magnitude of the load applied to the joint upon the value of the vertical movement between rail and bar, it may be said that for joints giving small movements there was little difference between the effects of the heavy and the medium load. For joints giving a larger vertical movement, in most cases the medium load gives a somewhat smaller movement, perhaps more nearly proportional to the moment developed in the joint. For the joints on which the low load was also applied, joint 46 gave negligible movements at all points for low, medium, and heavy

loads. For joint 48 the movement at the middle of the bars was largely developed by the low load. It is evident that the vertical movement between rail and bar is mostly due to play between bar and rail and to a less extent to a bending of the rail and bar and to slipping of the bar on the bearing surfaces.

A comparison of the sum of the vertical movements between rail and bar at two or more points and the moment developed in the two joint bars does not show the proportionality between movement and moment that was noted for some of the tests in the Fifth Progress Report. The variability in the conditions of the rail support found in the track introduces variables which have a greater effect on the moment developed than was produced by the small play between rail and bars.

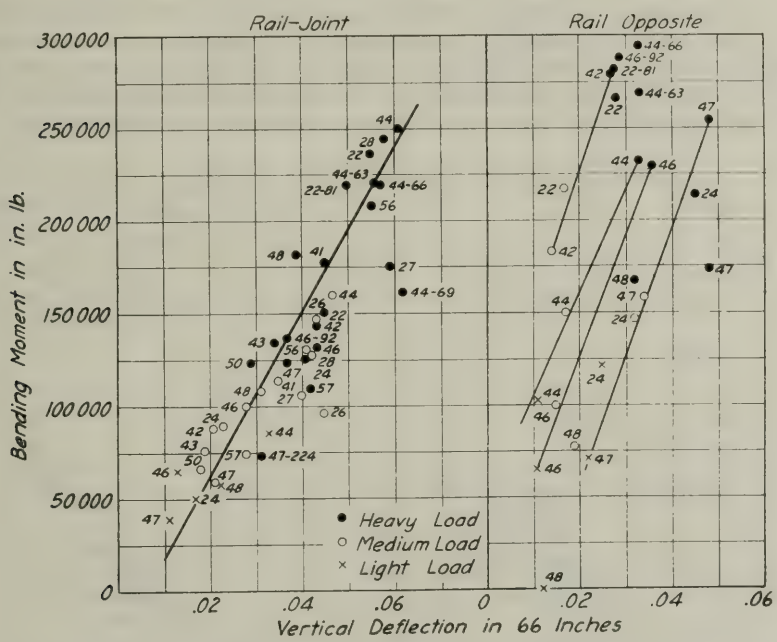


Fig. 55.—Vertical Bending Moment in Two Joint Bars and in Rail Opposite and Gross Deflection in 66 in. for Light, Medium and Heavy Loads—Tests on Chesapeake and Ohio Railway.

In Fig. 55 the measurements of the deflection of rail-joint and adjacent rail in 66 in., with the mid-point of the 66-in. bar resting on the joint bars at mid-length, are plotted as abscissas and the moment developed in two joint bars at mid-section as ordinates for the heavy and the medium load and in a few cases for the light load, including the joints tested with loose bolts. The general trend of the deflections is in the direction of the straight line shown. If the points for a heavy and a medium load on a given joint are connected and also the point for a light load when applied, the lines are generally roughly parallel to the line shown in the figure. The deflections and moments, then, are fairly proportional to increases in moment regardless of how the rail supports may be varied.

The deflection in 66 in. and the moment developed in full rail at a section directly opposite the joint are also plotted in Fig. 55. The average deflection in the full rail for a given moment is roughly about 60 per cent of the deflection of a rail-joint for the same moment as given in the diagram. It will be noted that light lines connecting the points for heavy, medium and light loads at a given location are generally roughly parallel to each other so that the deflection of the full rail may be called proportional to increase in load.

It was not observed that the slight inclination of a joint bar from the vertical position (cocking) in one bar of a few joints had an effect on either vertical movement or deflection in 66 in.

30. **Vertical and Lateral Deflection of Joint Bars.**—The vertical deflection of the outer bar in 25 in. and in 37 in. was measured with the three points of the deflection bar resting on the top surface of the joint bars. These measurements were made on 39-in. bars for the original condition of the joints including both tight and loose bolts and on changed bolt tension and also on the two pairs of bars shortened to 26 in.

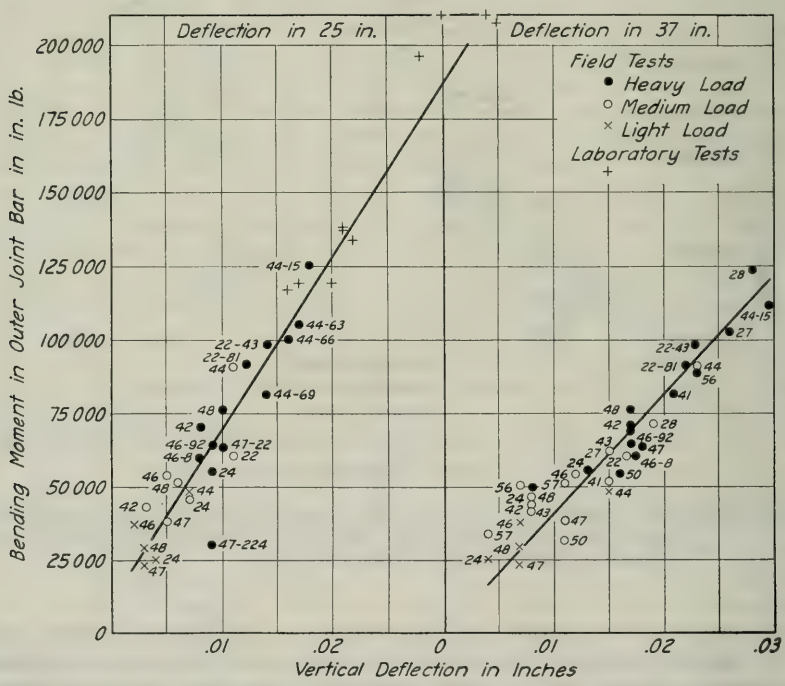


Fig. 56.—Vertical Bending Moment in Outer Bar and Vertical Deflection of Outer Bar for Light, Medium and Heavy Loads—Tests on Chesapeake and Ohio Railway—Together with Some Results of Laboratory Tests.

In Fig. 56 are plotted the moments at mid-section of outer bar and the corresponding deflection of the bar in 25 in. and in 37 in. as found with the heavy, medium and light loads. It is seen that except for some small values of the moment the concordance is rather close—the spread of the deflections for a given moment is less than might be

expected. The relatively small variation from the general rate of deflection means that the position of the centroid of rail pressure on the top fishing surface of the bar and that of the centroid of the reactions on the bottom fishing surface do not differ greatly in relative location regardless of bolt tension and looseness and tightness of joint, though of course some variation is apparent It is evident, too, that there is little moment and therefore little curvature in the bars towards the ends of the 25-in. chord. The deflection in 37 in. also gives concordant results with reference to the moment developed at mid-section. As compared with the results with the 25-in. deflection bar they indicate relatively little bending curvature through the outer portions of the chord length. It was found also that the deflections of the outer bars in 25 in. and 37 in. gave good concordance with the deflections of the joints in 66 in. discussed in the preceding article.

In Fig. 56 are also plotted the deflection in 25 in. found in laboratory tests of the joints with the same Santa Fe symmetrical bar section of 26-in. length and applied moments of 120,000, 150,000 and 200,000 in.-lb. in one bar. The continuity of the results may be interpreted to mean that flexure of the 39-in. joint bars in the field tests and that of the 26-in. joint bar in the laboratory tests agree closely in position of centroids of bearing pressure and reactions and in deflections in 25 in. The field tests also include two joints with 26-in. bars.

The lateral deflection of either bar in 25 in. taken at the neutral axis of the bar was generally small, of the order of 0 to .002 in. or a little more, (either inward or outward) and had a more or less local character, so that the measurement cannot be taken to have general significance.

V. TRACK DEPRESSION AND RAIL STRESSES IN TESTS ON THE CHESAPEAKE AND OHIO RAILWAY.

31. **Description of the Track.**—The tests were made in September and October 1931 on the westbound freight track of the three-track line of the Chesapeake and Ohio Railway (No. 1, the outer track on which the tests of rail-joints having the symmetrical type of bar were conducted), one and one-half miles west of Ashland, Kentucky. This track was built in 1924. On the tangent stretch on which the tests were made the embankment height was 4 ft. to 8 ft., except in the neighborhood of joints 26 to 28 where it increased to 12 ft. The roadbed evidently had become thoroughly compacted. There was 8 in. or more of heavy limestone rock ballast under the ties (large size broken stone free from fine particles) over a bed of gravel ballast which extended down 2 ft. or more. The stone ballast continued on one side to the ballast of No. 2 track and on the outer side it ran from 4 in. below the top of the tie, sloping outward with a full shoulder. Between rails (due to the recent re-surfacing) the ballast did not come within 2 or 3 in. of the top of tie. The ties were 8 ft. 6 in. long and generally about 7 in. deep. The width of the tie varied considerably, ranging from 8 in. to 12 in. The ties were treated oak. Most of the ties were laid in 1924, but some renewals had been made. All but a very few were in good sound condition, though a number were badly split at the ends. The rail was 130-lb. R.E. laid in March 1931. In laying the new rail, new tie-plates, 7½ by 12 in., with an eccentricity of ⅛ in. and an inclination of 1 in 28, were applied with only a limited amount of tie adzing. A cut spike was driven on either side of the rail. The rail ends were laid rather tight, and at the time of the tests a number of rail ends had been chipped somewhat. At the time of laying the new rail it is reported that the ties on the tangent track were not re-spaced and no general tamping of track was done at that time. About four weeks before the track tests were under

way, the ties were re-spaced to a certain extent, the ballast forked, and the ties hand-tamped with slight raising without adding more ballast. It was stated by the section foreman that the joint ties were tamped harder than the others. As will be described later, the tie spacing was not very regular, the tie-plate bearings were uneven and partially out of the rail base plane, and the unloaded rail failed to rest on the tie-plates for several consecutive ties from place to place along the track. Although the bearing of the tie-plates may not have varied much from ordinary practice the bearing conditions were quite in contrast with track with ties adzed and bored in such way as to ensure that all tie-plates have even bearing and lie in the same plane, as is the practice on some railroads. Nominally the cant of the rail was 1 in 28. Measurements made on the unloaded rail at 63 places along the track showed that on the north rail (on the side away from the other tracks) the range in the cant of rail was from 1 in 21 to 1 in 35 (averaging 1 in 27), and on the south rail from 1 in 13 to 1 in 23 (averaging 1 in 16). The difference in cant of the two rails was evidently due to differences in the adzing of the tie for the tie-plate bearing for the two rails along this stretch of track. The rail-joints have been described in Chapter IV.

The track carried very heavy freight traffic. At the time of the tests, fifteen or more trains of 110 to 130 loaded coal cars of 50- and 70-ton capacity moved westward during the day, most of which were diverted to track No. 2 for accommodation of the test work. The information was given that during this time the movement of traffic which would regularly go to track No. 1 was at the rate of 60,000,000 tons a year, which though not up to the normal traffic is exceedingly heavy. In fact, this stretch of track is known as having the heaviest tonnage on the road and this tonnage is rarely if ever exceeded on any railroad. It is evident, then, that four weeks of this heavy traffic would be likely to bring the track surface down to what may be considered to be normal surface conditions. It should be noted that the speed of these heavy trains was slow, never over 25 miles per hour.

32. **Methods of Testing.**—The same steel hopper coal cars of 70 tons capacity were used as in the tests of the rail-joints. As before, the loads on the test end of the cars were 26,000 lb. for the light load, 59,500 lb. for the medium load, and 119,800 lb. for the heavy load, which have been called 6500 lb. per wheel for the light load, 15,000 lb. for the medium load, and 30,000 lb. for the heavy load. In tests of track depression, the car was kept in place until levels had been taken on rail and tie and tie-plate along the given stretch of track. In one test the levels were taken only at the tie just below the end wheel for spottings on seventeen consecutive ties. For the tests to find stresses in rail an end wheel was spotted at the desired point, generally directly over a tie, and after the measurements were made the car was moved to the next point, and thus on from point to point along the rail. The stresses in rail were measured at the two edges of the base of rail at gage lines just inside the upper outer corner of the rail base and 0.52 in. vertically above the bottom of the rail, using a Berry strain gage of 2-in. gage length.* As in the tests of rail-joints the Berry strain gage was used by a skillful and experienced operator and it is believed that because of the smaller chances for temperature variation in the shorter intervals of time required for taking the data the results are subject to less error than those for the rail-joints. In the measurement of stresses in rail only the heavy load was used except at points opposite the rail-joint. Zero strain

* A reference to a description of the Berry strain gage and its use is given in Article 6 "The Laboratory Tests of Rail-Joints".

gage readings were taken before the load was applied and afterward. The deflection of the rail was taken with a 66-in. deflection bar at points opposite the rail-joints tested.

The method of determining the track depression involved taking levels along the track with an engineer's level for the track unloaded, loaded with light, medium, and heavy load, and again in an unloaded condition. The level was also used in making push-down and pull-up tests. A special level rod (see Fig. 93) 6 in. long with the scale graduated to one-hundredth inch was generally read to one-hundredth inch but sometimes half-hundredths were read in getting the vertical movement between rail and tie-plate, tie-plate and tie, and for other purposes. A spherical bubble attached to the level rod aided in giving accuracy. The levels were taken with the pointed end of the level rod placed in a punch mark in the base of the north rail near its outer edge above the middle of the width of each tie and in a punch mark on a nail in the tie about 1 in. away from the outer edge of the north tie-plate, and also at the south rail for the two ties between the wheels of the rear truck. For each test location these levels were taken at each individual tie from a tie about the middle of the length of the test car to a tie about 15 ft. behind the rear wheel of the rear truck. The engineer's level was placed about 10 ft. from the rail and opposite the space between the two wheels of the rear truck. Check readings were taken on nearby bench marks. To insure accuracy one man carefully kept the instrument level while another took the readings. Levels on punch marks on a few tie-plates near the wheels of the rear truck were also taken. Other observations were made for special purposes. It should be noted that the frequency and length of trains on the other two tracks put practical obstacles in the way of taking levels along the south rail except for the two ties between the wheels of the rear truck as noted above. Information on the stiffness of track along the south rail would have been of value in making comparisons.

33. **Tests of Track Depression.**—From the tests of track previously made, it is to be expected that the depression of rail caused by the application of a light load will be greater proportionally than that of heavier loads and that the added depression of the heavier loads will in general be approximately proportional to the difference in the two loads. It is also to be expected that part of the rail depression found with both light and heavy loads will be due to play existing between rail and ballast bed and hence this portion should not be considered in determining the stiffness of the track.

In Fig. 57 to 61 the results of the gross depression measurements of rail and tie for light, medium, and heavy load for the five locations at which levels were taken are plotted as ordinates at each tie including six ties at each end away from the two wheels of the car truck, and for convenience these points are connected by lines. The dashed line at the upper part of each diagram (named the derived play curve) represents the play between the rail and the tie bed as found by subtracting from the gross depression with the light load a quantity found by multiplying the excess of the gross depression with the heavy load over that with the light load by the ratio that the excess of weight of the heavy load over that of the light load bears to the weight of the light load. This calculation is based on the assumption that the light load has brought both rail and tie to a firm bearing at each tie and that the further depressions made by the heavy load are everywhere proportional to the added load taken by individual ties. However, it will be seen by Article 35 that in some cases the light load has not produced a firm bearing at some of the ties. It should be noted that the depression measurements toward the ends of the diagram and the derived play at the same places are not representative of the individual tie load conditions at this part of the diagram for the reason that the actual

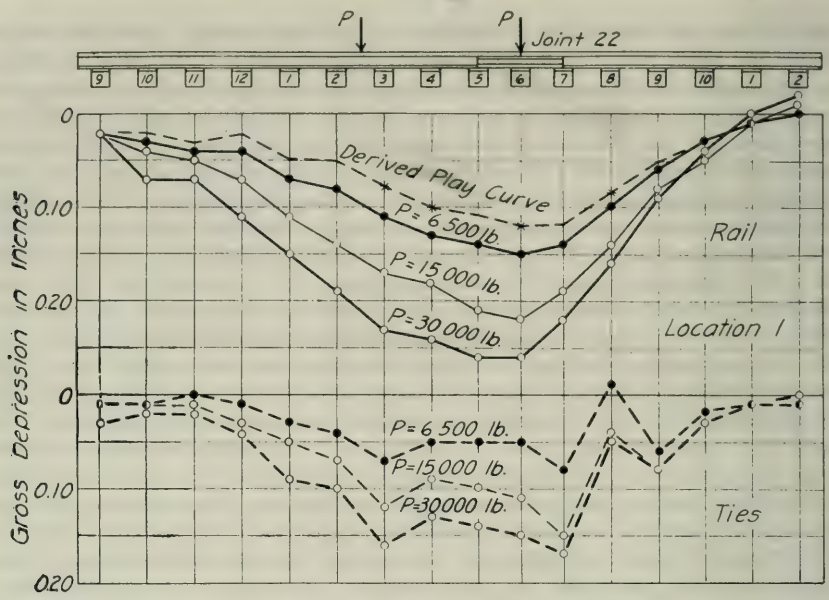


Fig. 57.—Gross Depression of Rail and Tie for Light, Medium and Heavy Load and Derived Play Curve at Location 1—Tests on Chesapeake and Ohio Railway.

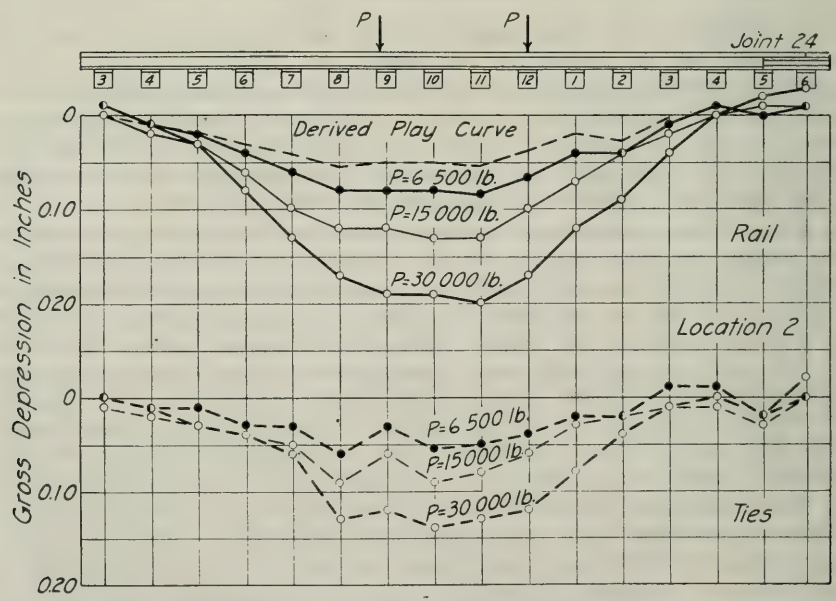


Fig. 58.—Gross Depression of Rail and Tie for Light, Medium and Heavy Load and Derived Play Curve at Location 2—Tests on Chesapeake and Ohio Railway.

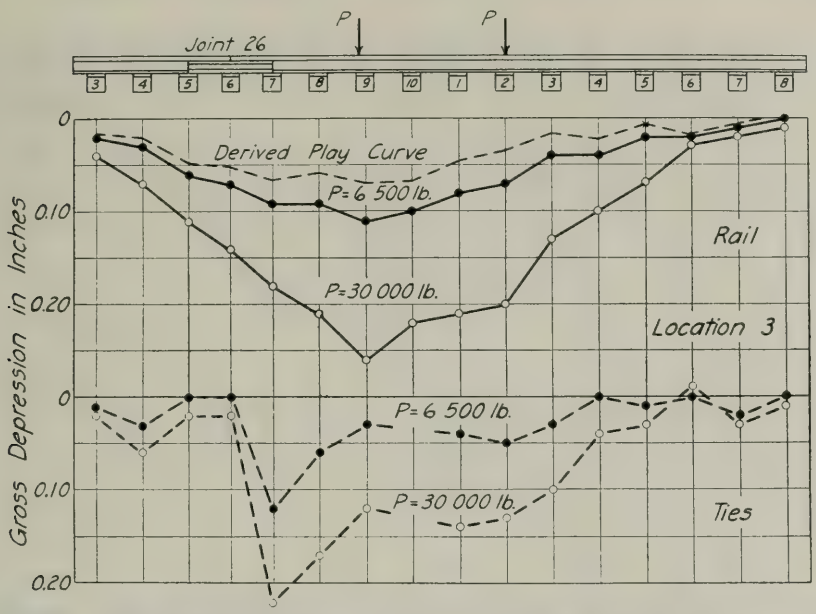


Fig. 59.—Gross Depression of Rail and Tie for Light and Heavy Load and Derived Play Curve at Location 3—Tests on Chesapeake and Ohio Railway.

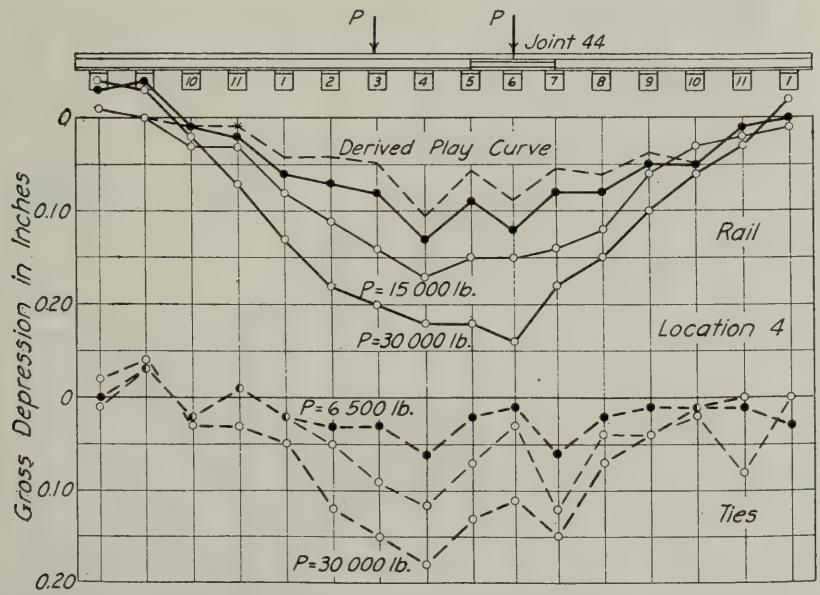


Fig. 60.—Gross Depression of Rail and Tie for Light, Medium and Heavy Load and Derived Play Curve at Location 4—Tests on Chesapeake and Ohio Railway.

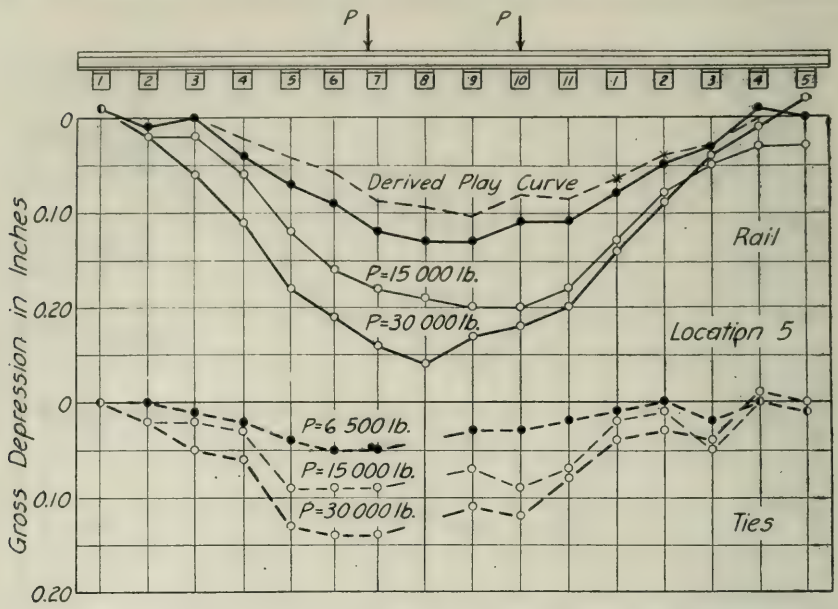


Fig. 61.—Gross Depression of Rail and Tie for Light, Medium and Heavy Load and Derived Play Curve at Location 5—Tests on Chesapeake and Ohio Railway.

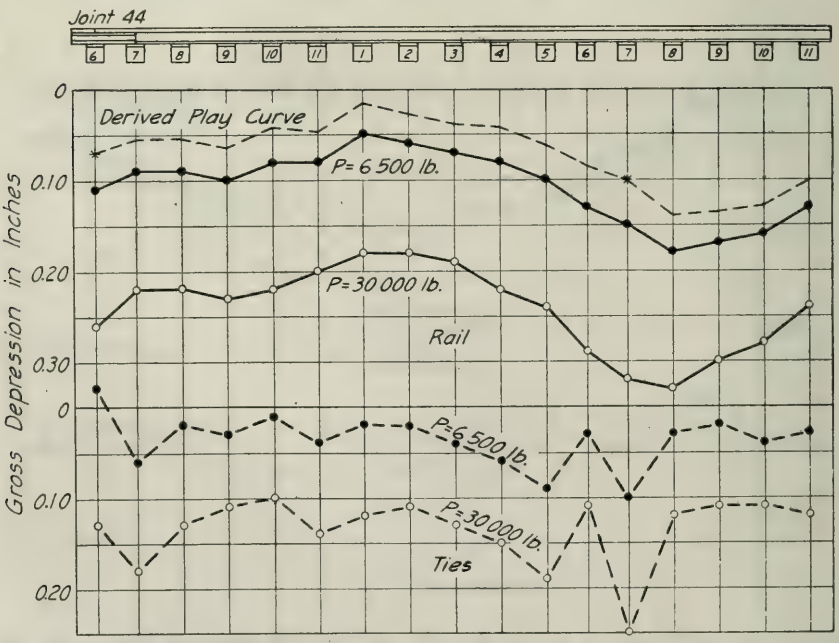


Fig. 62.—Gross Depression of Rail and Tie at the Rear Wheel when the Load is Moved from Tie to Tie—Light and Heavy Loads—Together with Derived Play Curve—Tests on Chesapeake and Ohio Railway.

vertical play of rail and tie at these places is generally greater in amount than the gross rail and tie depressions. It should also be noted that upward movement of the rail and tie will not be representative of actual negative vertical pressures acting on the rail. By comparison with the data of the pull-up and push-down tests in Fig. 64, 65, and 66 it will be seen that the ordinates of the curves marked "derived play" in Fig. 57 to 61, though usually in fair agreement with the sum of the pull-up and push-down tests except at or near the ends of the length of the diagram, are frequently somewhat less than this sum, because of the fact that the light load has not brought the rail down to a fair bearing at every tie and that the rail has bridged over two or more tie spaces. Examples of this failure to take load are indicated by an asterisk in the figures.

Tests were made by spotting the end wheel of the car truck at points immediately over consecutive ties, beginning at joint 44 and running west on the north rail and measuring the rail and the tie depression directly under this wheel by means of levels at each of seventeen load positions, no readings being taken at points away from the wheel. At the top of Fig. 62 are plotted the measurements of rail depression for the light load and the heavy load and at the bottom the corresponding tie depression; a plotting of the derived play curve for the rail is also shown. It is evident that both rail depression and tie depression have considerable variation along the track. The depression of the rail at the highest point of the curve for the heavy load is .18 in. and that at the lowest point is .33 in., and the range in the position of the play curve is from .02 in. to .14 in. Not only is the range great, but it must be true that the stiffness of the 130-lb. rail acts to bridge over many inequalities in the rail support and that without this stiffness its variability would be much more apparent. The variability in the gross depression of the tie directly under a wheel load given in the lower part of the diagram is marked and erratic. This is due largely to the variation in the play between rail and tie along the track.

In Fig. 63 the net depression of the rail and the tie in the consecutive tie loadings given above for the light load and for the heavy load is shown, the value having been obtained by subtracting the ordinate for the derived play curve from the corresponding gross depression at every tie given in Fig. 62. The line of net rail depression for the light load seems fairly uniform but by comparison it is seen that the value at the lowest point is 50 per cent greater than that at the highest point. This ratio likewise holds true for the corresponding points in the line for heavy loads. The values for the net tie depression have considerable variation—ranging from .09 to .19 in. for the heavy load. It is evident that the variation in tie load for a given spot may be even greater than is indicated by the variation in net ordinates, for the stiffness of the rail helps to place upon stiffly bedded ties much greater loads than their normal share.

34. **Elements in the Total Rail Depression.**—The vertical movement between the rail and the tie's bed in the ballast may be considered to be made up of (a) play between rail and tie-plate, (b) play between tie-plate and tie including any vertical movement of tie-plate due to imperfect bearing of tie-plate on the adzed surface, (c) compression of the tie throughout its depth when load is applied through the tie-plate, and (d) play between bottom of tie and its ballast bed including bending of the tie to reach the bed directly under the rail. Below the tie bed the elastic vertical compression of the ballast still further increases the downward vertical movement of the rail under load by .05 to .15 in. for stiff ballast and medium to heavy loads. The inelastic down-

ward movement of the ballast, after the track has been in use, is extremely small and may be neglected for the purpose in mind.

Tests were not made to determine precisely the division of the play among the several vertical movements between rail and tie bed. The vertical movement between rail and tie-plate was markedly large, ranging from 0 to .15 in. or more. This play between rail and tie was quite variable from tie to tie and from a group of two or more ties to another group of ties. This variability in the play is an important source of the marked variation in stress in rail found from point to point along the track. The heads of the spikes in most cases were found to be high enough above rail contact to permit full play.

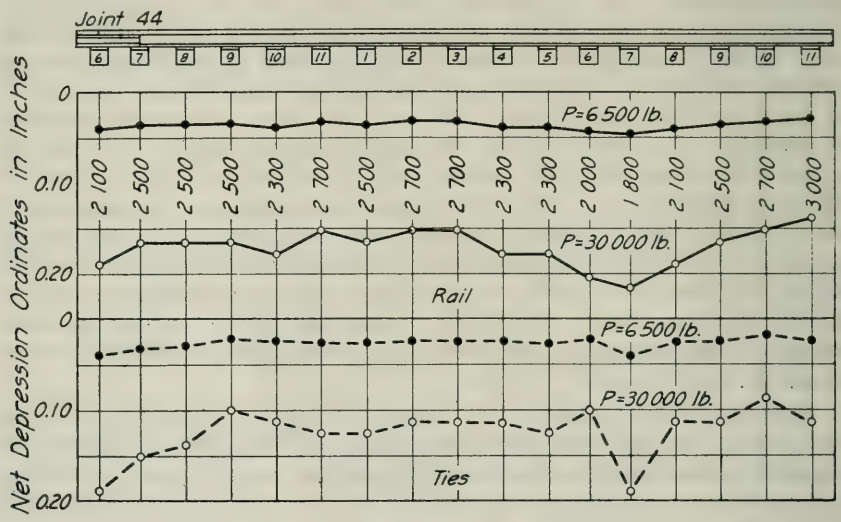


Fig. 63.—Net Depression of Rail and Tie at the Rear Wheel when the Load is Moved from Tie to Tie, Together with Modulus of Elasticity of Rail Support Calculated from Rail Depression at Rear Wheel—Tests on Chesapeake and Ohio Railway.

Although the average play between tie-plate and tie was not large over the whole tie-plate, there was evidence of sufficient unevenness of bearing between tie-plate and tie to give eccentric reactions between the rail and the tie, which contributed largely to the variability of stress at the two edges of the base of rail and to twisting in the rail. Similarly differences in the planes of the base of rail and the bearing face of the tie-plate caused eccentric reactions.

As is reported elsewhere, the play between tie and ballast bed was found to be small (generally 0 to .03 in.)—that is, the ties were not generally held up above the ballast bed by the rail and spikes—but of course flexure of the tie to fit the tie bed was generally developed under the load.

35. **Vertical Play or Looseness between Rail and Tie and between Tie and Ballast Bed.**—A purpose of the tests was to learn what vertical play or looseness exists at individual ties between rail and tie and also what exists between tie and ballast bed. The test to find the play between tie and ballast bed is termed the push-down test and that for the play between rail and tie the pull-up test, the later term being substituted for "hook-up" used in the Fifth Progress Report. In these tests levels were taken accurately on a nail inserted in the tie about 1 in. away from the outer edge of the tie-plate, both for the original position of the tie and when a downward or an upward force was applied to the tie. The level readings were taken at both rails and on the two ends of a tie. In the few cases where the spike did not have full clearance from rail base it was pulled slightly to allow clearance.

In the push-down test a bar was placed under the rail head and over a fulcrum block resting on the tie at the gage side of the rail, and downward pressure was exerted by a man at the further end of the bar. The resulting pressure on the tie (probably about 1,000 lb.) was usually sufficient to set the one end of the tie fairly well on its ballast bed or at any rate to hold it very nearly in that position. The difference between the level readings on the tie before and when the force was applied gives the vertical movement required to seat the one end of the tie on its ballast bed at the given end. In most cases where the movement was large the other end of the tie rose somewhat.

The pull-up test was made by inserting the bar through ballast under the end of the tie, using a short block as a fulcrum, and applying pressure at the further end of the pry. The effort was made to exert just enough pressure on the pry to bring the rail and tie-plate and tie into contact, and level readings were then taken. The difference in the readings on the tie for the original position and for that taken when the force was applied gives the play between rail and tie.

It should be understood that the method of making the pull-up and push-down tests was not closely accurate. The amount of the force exerted on the lever in the pull-up test may sometimes have been too great, and the rail itself may have been lifted somewhat. Possibly some ties may have rocked or tilted on a support at their center and there may have been lateral twisting in the position of the tie. In some cases the push-down test may not have seated the tie fully on its whole bed. However, the method was readily and quickly applied, the possible errors were small, and the results are considered to be significant.

The values of the movement between tie and ballast bed found in the push-down test are usually small—generally .01 in., frequently .02 in. and in 35 places out of 434 observations the movement was .03 to .05 in. This means that ordinarily when the rail is without load the ties generally lie fairly on one or more points of the ballast bed. It should be noted that this is the usual position taken with a very light load; it does not mean that the tie is in contact with its ballast bed all along its length, for the loaded cars will put flexure into the tie, bending it to fit the curved ballast bed, and of course it does not include the depression of the ballast bed itself when loaded wheels are applied to the rail.

The results of the pull-up tests indicate the amount of vertical play between rail and tie in an unloaded condition, and those of the push-down tests the amount of the vertical play between the unloaded tie and its ballast bed. To show the distribution and the grouping of the variability, the data for several stretches of track have been plotted

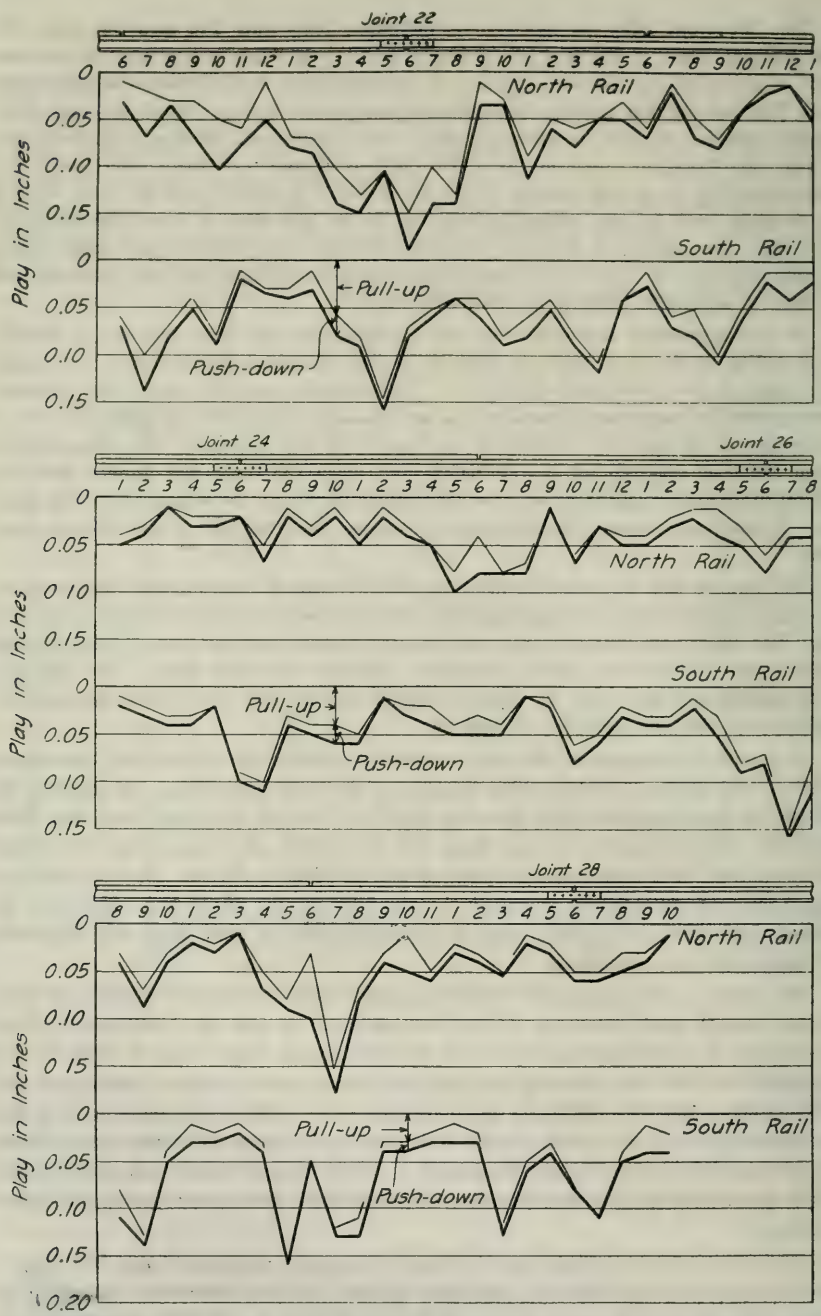


Fig. 64.—Vertical Play between Rail and Tie and between Tie and Ballast Bed as Determined by Pull-up and Push-down Tests—Tests on Chesapeake and Ohio Railway.

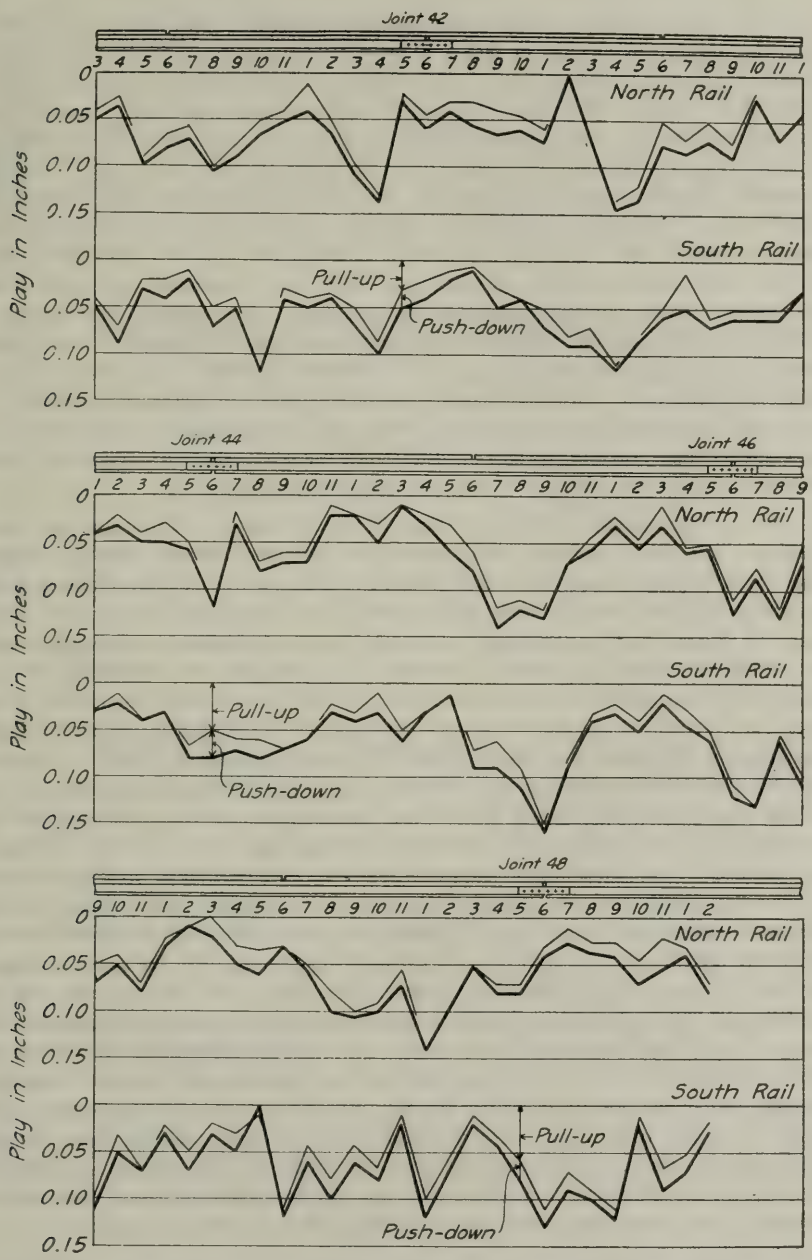


Fig. 65.—Vertical Play between Rail and Tie and between Tie and Ballast Bed as Determined by Pull-up and Push-down Tests—Tests on Chesapeake and Ohio Railway.

in Fig. 64, 65 and 66, with values obtained at every tie for both the north and the south rail. The distance of one set of points below the base line gives the vertical distance measured from the normal position of the unloaded rail to the resting position of the unloaded tie, as found by the pull-up test, and these points are connected by a light line. The distance from the resting position of the bottom of the unloaded tie to a position on its bearing bed directly below the rail, as found by the push-down test, is plotted downward from the points on the light line, and the points so plotted are connected by a heavy line. The ordinates of the heavy line then represent the total vertical play between rail and tie bed. Owing to the method of lifting the tie used in the pull-up test an error of observation of .01 in. or possibly of .02 in. may occasionally have been made, and consequently an individual point may be considered to be subject to inaccuracies of the order of these amounts. To aid in interpretation it may be remarked that a continuous 130-lb. rail supported every 15 ft. will deflect less than .01 in. under its own weight and that even if the supports are unevenly spaced the maximum deflection in this length will generally not exceed .01 in. The tests recorded in Fig. 64, 65 and 66 include track at and near the location of all the tests on rail joints, rail stresses, and track depression, and for the most part values are given for consecutive ties.

The total play given in Fig. 64, 65 and 66 varied from 0 to .19 in. and one value of .25 in. The average for the 434 measurements was about .064 in. The most significant feature of these values lies in the variation in play from tie to tie or from a group of from two to five ties to another group of ties lying adjacent in either or both directions. It is seen that the variation in grouping and in depressions is large and varied and results in abrupt and frequent variations in the rail support. Sometimes the rail touches the tie at adjacent ties and and sometimes no contact is made for twelve ties or more. It is seen from the figures that hills and hollows are grouped in various combinations ranging in clusters from three or four to ten or twelve ties. A study of the diagrams is of interest then in indicating stretches of rail without support, in showing groups of high ties and low ties, and in bringing out the markedly uneven contour of the rail support. A tie fairly close to the rail may be called a high tie and on this stiff ballast one more than, say, .04 in. below the rail a low tie. As an example, in Fig. 64, on the north rail one support for the unloaded rail is six tie spaces east of joint 22 and the next is three tie spaces west, while to the right the next six ties are fairly well below the rail, and to the left the next three ties are somewhat below the rail. On the south rail opposite joint 26 the unloaded rail has no support for six ties, then four ties give support, then four ties give poor support. A deep depression of the rail support is apparent near joint 56 in Fig. 66. Some ties and groups of ties will take abnormally high loads and others will take no load until the high ties have been depressed an abnormal amount or the rail bent so the low ties may receive load. It is evident that the supporting values of the ties when under load are very irregular and extremely variable from place to place along the track. This unevenness, it will be found, has an important and disturbing effect on the individual tie reactions when the load is applied to the rail and upon the intensity of the stress in rail at the high ties and the low ties along the track.

36. **Variation in Load Taken by Individual Ties.**—It is evident that play between rail and tie bed results in variations in the load carried by individual ties as the train passes over the track. The relative amount of load taken by individual ties may be estimated with a fair degree of accuracy for the purpose of comparison from the measurements of the pull-up and push-down tests and the amount of the average net rail depression for a given set of wheel loads by assuming that the total load is carried by a certain number of ties and that the load carried by an individual tie is proportional to the amount of the net depression of the tie when the load is applied—that is, to

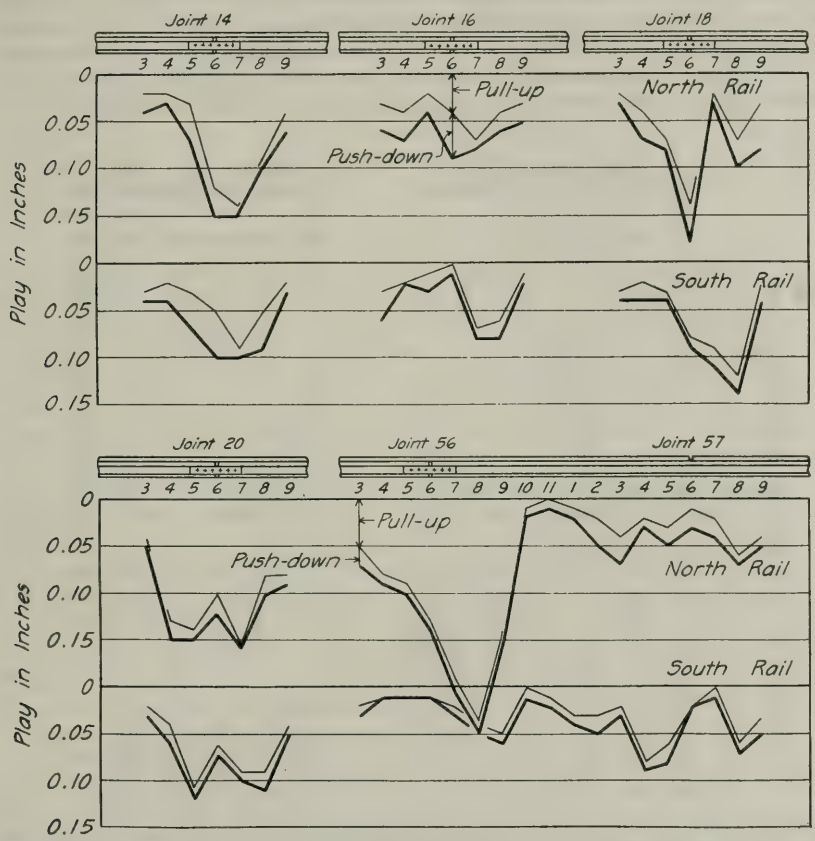


Fig. 66.—Vertical Play between Rail and Tie and between Tie and Ballast Bed as Determined by Pull-up and Push-down Tests—Tests on Chesapeake and Ohio Railway.

the amount the tie depresses after the play is overcome and it starts to take load. To make a simple illustration, one not likely to be found in track, suppose each alternate tie has a vertical play of .07 in. and that the remaining ties take load from the start. Consider also that the given load would produce a rail depression of .07 in. if supported

uniformly by all the ties. Then calling y' the rail depression for uniform support and y the depression for the ties under the conditions assumed,

$$y' = .07 = \tfrac{1}{2}(y + y - .07)$$
$$y = .105$$

It follows that the load carried by the high ties will be 1.50 times the average tie load and that by the low ties only .50.

If the play at the alternate ties were .14 in. and the depression under uniform tie support remained .07 in., then the high ties would take 2.00 times that for uniform tie support and the remaining ties would take nothing. On the other hand, if the track substructure is less stiff and the depression on a uniform support is .21 in. for the given load instead of .07 in. and the vertical play of alternate ties remains .07 in., the high ties will take only 1.17 times the average load and the low ties .83 times the average load. It follows that for the same range of vertical play a stiffly supported rail may be expected to have a greater variation in tie loads than a rail less stiffly supported.

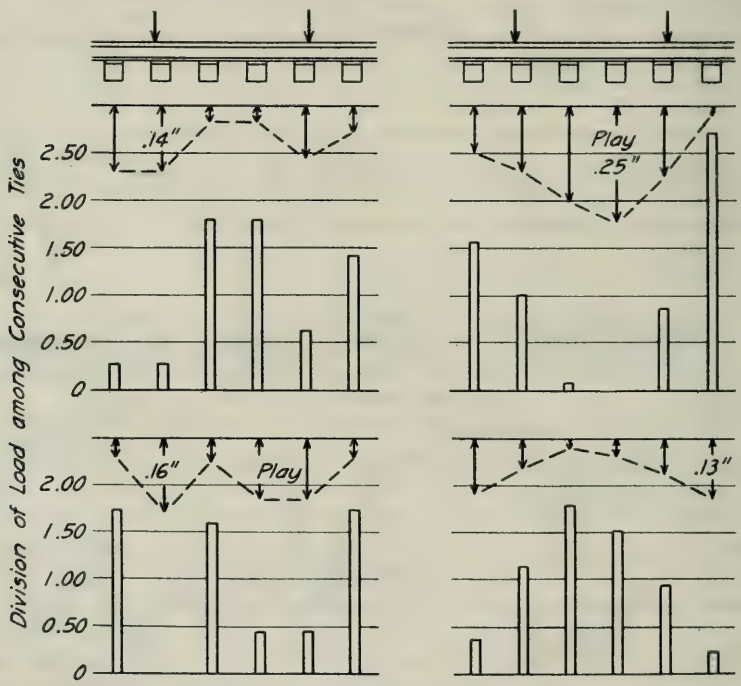


Fig. 67.—Estimated Division of Load among Consecutive Ties Based on Pull-up and Push-down Tests—1.00 Represents Uniform Division—Tests on Chesapeake and Ohio Railway.

For a careful determination of the reactions the full length of the depressed track will of course need to be taken into account, but for obtaining approximate values the inclusion of a few ties outside the wheel group in making the calculations of track depression will permit a fair comparison to be made.

As examples of quite variable conditions found in the track, Fig. 67 gives plottings of total play between rail and tie bed taken from the pull-up and push-down tests for

groups of ties at four locations. To get a conception of the variation in the distribution of load among the various ties, consider that for a medium load 90 per cent of the 30,000 lb. load on the two wheels is carried by six ties and that the average net rail depression at these six ties is .07 in. Consider further that the stiffness of the rail would produce approximately equal depression for these six ties if no play existed. On these assumptions the division of load among the six ties will be represented by the vertical lines, the values being given in terms of the load carried by uniformly loaded ties as unity, as would be approximately true with absence of play. It will be seen that the range in individual tie load is from 0 to 2.7 times the average tie load. The four diagrams shown were selected at locations which give a striking variety of distribution of tie loads. It is evident that with such groupings of tie loads great variability in bending moments will be developed in the rail at different points.

If the heavy load (60,000 lb. on two wheels) had been used, the variations from average load of course would not be so great. For the play given in the upper right hand diagram of the figure, the proportion taken by the tie at the right is 1.8 instead of 2.7, but the two middle ties take .3 and .6 times the average load. In the upper left hand diagram the ratio 1.8 drops to 1.40. The distributions even with the heavy load are far from uniform.

A study of the amount and distribution of the vertical play between rail and ballast bed recorded in Fig. 64, 65 and 66 shows that there are many variations in play and in the groupings of play at different places along the track and therefore that there must be great variability in the amount and distribution of individual tie loads. Approximate calculations made on the assumption that the load carried by a tie is proportional to the further depression of the rail after the play at the given tie has been overcome emphasize the part that the distribution of the variation in play must have in modifying the magnitude of individual tie loads and the stresses in rail from point to point along the track. For the medium load of 15,000 lb. on each wheel of a freight car truck two adjacent ties may take 0 and .1 of their share of the load and one tie beyond each way may take more than their share. Other cases are found where one tie takes more than twice its share of load and adjacent ties less than half of their shares. Variations of a third more or less than the normal share are frequent. It is evident that two kinds of consequences result from these variations—(1) the abnormally heavy loads give undue load effects on certain ties and the ballast underneath, and (2) when ties carrying no load or light loads are between ties having little or no play the stresses in the rail must be markedly increased. The first effect results in lack of uniformity in wear and maintenance; the second may cause injurious effects in the rail—both contribute to roughness in track and require increased maintenance.

Again it will be seen that the variations in the tie loadings will be relatively less marked with the heavy load, but the difference will still affect the tie and ballast loads. It will also be found that the variations in stress in rail are very marked for the heavy load. The principal source of the variations in stress may be traced to the variations in rail support.

37. Values of Modulus of Elasticity of Rail-Support u.—In the analysis of the action of track as an elastic structure under load, the term modulus of elasticity of rail-support u is introduced as a measure of the vertical stiffness of the rail support. It is defined as the pressure per unit of length of each rail required to depress the rail one unit. It represents the vertical stiffness of the ties, ballast and roadway, but does not involve the stiffness of the rail, though of course the flexure of the rail in the track is affected by the value of this modulus in the manner set forth in the analysis. For the

units in use on American railroads, the value of this elastic constant is expressed in pounds per inch of length of one rail per inch of average rail depression.

The accompanying vertical reaction or vertical force against the rail (principally an upward force) on the assumption of a continuous elastic rail support and a constant modulus u has a relation to the vertical depression of the rail in the analysis given by the equation

$$p = -uy \qquad (6)$$

where p is the upward pressure against the rail per unit of length of rail at any given point (intensity of pressure) and y is the depression of the rail at the same point. For a given wheel load or group of wheel loads it is evident that the sum of the wheel loads on one rail will be equal to the sum of the reactions against the rail found by substituting the average of the rail depression throughout the length of the depression curve in this equation and then multiplying the resulting value of p by the length of the depression curve. The general form of the depression curve given by the analysis for two wheel loads of a truck is shown in Fig. 68. For the parts of the curve that rise above the original position (AB and EF) the analysis assumes that the uplift involves a downward pull on the rail proportional to the uplift and dependent upon the same modulus. The reaction forces are continuous and at any point vary in magnitude in proportion to the ordinate of the rail depression curve, whether positive or negative.

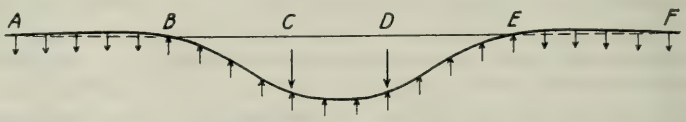


Fig. 68.—Form of Rail Depression Curve for Two Wheels Given by Analysis.

The analysis and formulas for the action of track as an elastic structure, referred to above, are given in the First Progress Report of the Special Committee on Stresses in Railroad Track (Proceedings, A.R.E.A., Vol. 19, 1918). A further application of the analysis is given in the Second Progress Report (Proceedings, A.R.E.A., Vol. 21, 1920). The equations for moments and depressions and other properties, as well as the master diagram, are repeated in the Fifth Progress Report (Proceedings, A.R.E.A., Vol. 31, 1930). Equations (7), (8), and (9) are given in Article 56 "The Analytical Consideration of Depressions, Stresses and Moments in Rail" of this report, and the master diagram for depressions and moments is also reproduced in Fig. 88.

Although the rail support in the track is not continuous, with the close spacing of ties generally in use and for values of u obtained from the track as built the analysis applies fairly accurately for well-built and well-maintained track so far as the discontinuity of the rail support is concerned. In the analysis it is assumed that beyond the ends of the downward part of the depression curve there is for some distance an upward depression where the pressures act negatively with values that are still proportional to the u of the depressed track. The amount of this assumed negative pressure will generally be greater than the weight of the rail in the case of the heavier wheel loads. Since in ordinary track the tie will not be lifted with the rail by the spikes throughout this small upward depression and as the weight of the ballast generally is not tributary to the negative pressure the stretch of track beyond the downward depression will not entirely conform to the assumptions of negative pressure used in the analysis. The greatest upward movement calculated by the analysis for ordinary track

is about .02 in., a seemingly small value. For the two wheels of the freight car truck on one rail of a stiff track the magnitude of the downward pull on the upward part of the depression curve obtained by the analysis sums up at each end (A to B and E to F, Fig. 68) to about 3 per cent of the total load on the two wheels, an amount that is too small to need be considered in a determination of u. However, it should be stated that this small upward force situated at a relatively large distance from the wheels does have an important influence on the magnitude of the moment at and between the wheels.

A further word may be given in regard to the downward pull on the rail at the two ends of the depression curve. If the weight of the rail is the principal source of this downward pull, the rail may be expected to be free from its support when it rises as much as .005 in. (not counting the vertical play), and its full weight will be at once available. Because of the stiffness of the rail its weight may be brought into action for a greater distance along the track than is indicated by the analysis (and lifted higher) and this and the greater leverage of this longer length apparently largely compensates for deficiency in intensity of downward pull called for in the analysis.

Fortunately it is found even with variations from the assumed conditions that calculations based on the analytical method usually give values of the moments and the depressions throughout the main portion of the depression curve that for the heavier loads are fairly close to the average measured values, particularly when u is obtained by means of measured depressions throughout the depressed part of the curve on the same or similar track. Furthermore, the agreement will be closer in the case of a group of wheels like locomotive drivers and the wheels of a truck or of two adjacent trucks of coupled cars, where the analytical upward depressions due to one wheel act at a second wheel only to decrease the analytical downward values at the second wheel, so that the analysis for such loadings would not usually involve an actual development of upward depressions between wheels, and thus the lack in upward pressure is confined to points well beyond the outside wheels of the group. It is also apparent that within a group of wheels the analytical negative moment from one wheel acts at any given point to modify the analytical moment from an adjacent wheel at the same point and that under certain conditions a resulting negative moment will be developed at points between wheels. It may be concluded from information obtained in the tests to find the value of u and from experience in applying the analysis that the deficiency in negative pressures referred to may not be expected to affect the general usefulness of the applications of the analytical method in calculating the moments and depressions of the rail throughout the greater portion of the length of the depressed track.

A second element of variation from assumed conditions also needs consideration. For the usual conditions of track, play exists between rail and tie and tie and ballast bed in varied and irregular amounts from tie to tie, and this variability modifies the distribution of the upward pressure on the rail from tie to tie along the track. For this condition the assumptions that a fair bearing is generally reached at nearly every tie on the application of the light load (even though the load carried by consecutive ties may differ greatly) and that the further tie reaction at any tie is proportional to the further depression of the rail are useful approximations.

In the determination of u given in previous reports of the Committee the assumption was made that all the ties through the depressed length of the curve to or almost to the point where downward depressions change to upward ones carry load and should be included in the determination of u. It is apparent that this procedure gives values of u somewhat lower than the actual modulus because with large play or even medium play between rail and ballast bed there will probably be two or three ties at the ends of the

downward depression curve that will carry little or no load; that is, the play will prevent the rail from transmitting to these ties pressures of sufficient magnitude to be considered in the computations.

A study of the pull-up and push-down tests and the rail depression curves with light load and heavy load will show that ties near the end of the depressed length usually develop little or no reaction upon the application of the wheel loads and that these ties frequently should not be included in the number of bearing ties at which rail depressions are used in the calculations when the play at these ties exceed the corresponding values for the rail depression. On the track of the Chesapeake and Ohio Railway the load-carrying ties in the several test locations extend usually three ties beyond or outside the position of the two wheel loads and sometimes one or two ties further, and hence in the computations only the ties between these limits have been considered. At some of these locations one or more ties through the main portion of the depression curve were found by the pull-up and push-down tests not to be in condition to take reactions under the light load. However, it has been thought best to disregard those imperfect bearings, though a consideration of the deficiencies in these tie reactions would tend to increase the value u obtained from a given set of data.

The curves marked "derived play curves" in Fig. 57, 58, 59, 60, and 61 were obtained from the data of the tests on the assumption that the light load overcame the play at all ties and that the further rail depression beyond that of the light load (net depression) will be proportional to the added load given by the heavy load. The difference between the value of the rail depression for the heavy load and the ordinate of the derived play curve at any tie that carries load will be called the "rail net depression ordinate", this long term being used instead of "net rail depression" to avoid confusing these ordinates with the ordinates of the flexure curve of the rail itself. Under the assumptions used the load carried by an individual tie will then be proportional to the rail net depression ordinate. In Fig. 69 the rail net depression ordinates at the five test locations obtained as described above for the heavy load have been plotted for all the ties that are considered to carry load. Reference to the measurement of play between rail and tie bed found in the push-down and pull-up tests and recorded in Fig. 64, 65 and 66 indicates that ties near the end of the depressed length frequently do not carry load even on the application of the heavy load or possibly may take load only after the play has been overcome. Accordingly at the ends of the depressed length the ordinates in the figure indicate rail net depression values only to the amount given by the pull-up and push-down tests. Connected by dotted lines in the figure (Fig. 69) are also plotted values at ties at the ends of the depressed length found by means of the derived play curve but not considered to represent load carrying depressions.

In calculating the value of u for a given test location, the rail net depression ordinates at each tie considered to carry load are added, and the total wheel load on the one rail is then divided by the product of this summation of the rail net depression ordinates and the average tie spacing through the depressed length. This procedure assumes that the total upward reaction is equal to the summation of the useful depressions at the ties throughout the depressed length multiplied by the average tie spacing and by u, and that this reaction is numerically equal to the wheel loads on one rail. As an example, if the summation of the rail net depression ordinates at location 1 is 1.11 in. for 11 ties and the average tie spacing is 21.3 in. and the load of the two wheels on one rail is 60,000 lb., the resulting value of u will be 2500 lb. per in. per in.

In Table 21 are given the values of u for the five test locations calculated from the data plotted in Fig. 69. The range is from 2200 to 2900 and the average value is 2600 lb. per in. per in. These values indicate a stiff rail support, and the range in values is

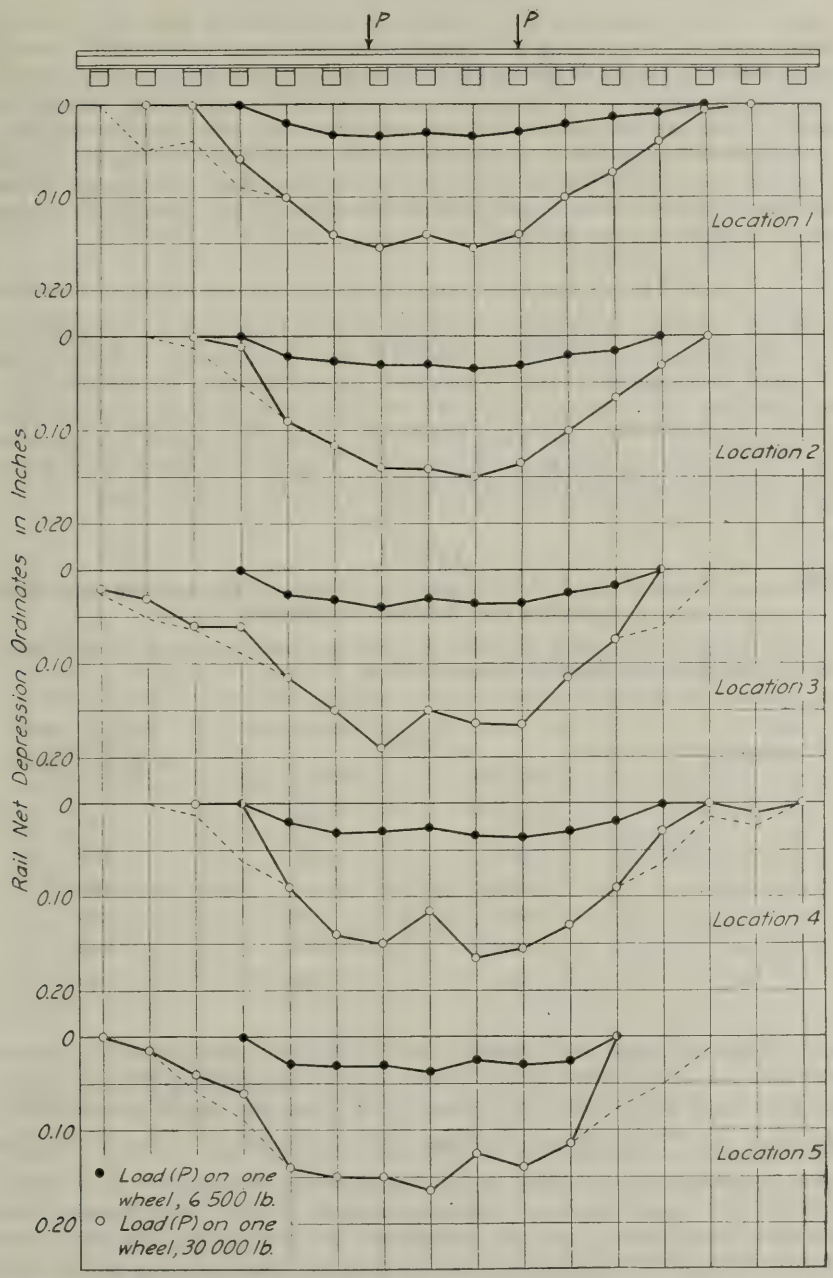


Fig. 69.—Rail Net Depression Ordinates for Light and Heavy Loads at Five Test Locations—Tests on Chesapeake and Ohio Railway.

relatively small. In passing it may be well to note that each of these values was obtained by the use of depressions at a number of ties and should be thought of as averages, and that on account of the marked variation in play from one or more ties to another small group of ties the stress developed in rail from point to point may be expected to be greater or less than the stress calculated from these average values of u.

An approximate method of deriving values of u consists in substituting the average of the two net rail depressions at the two wheel loads in the analytical equation for the depression at the two wheel points, which for the wheel spacing used and the average stiffness of the track tested becomes

$$u = k\sqrt[3]{\frac{P^4}{64\ EI\ y_1^4}} \qquad (9')$$

where P is the weight of one of the two wheel loads, y_1 the average net rail depression at the two wheels, E the modulus of elasticity of steel, I the moment of inertia of the rail section, and k the ratio of the depression at the two wheels to the depression at a single wheel for any given conditions. This procedure makes the value of u dependent upon the depression at the two wheel points only, instead of averaging the depression along the depressed length of track. Equation (9′) is obtained by finding by the analysis and master diagram of the First Progress Report (see Fig. 88 of this report) the additional depression at one wheel position given by the second wheel load for an assumed value of u and for the given distance between wheels, then expressing the depression at and for a single wheel load (y_0) in terms of the depression for the two-wheel load (y_1) (thus, $y_0 = \frac{y_1}{k}$), substituting this value of y_0 in equation (9) of the First Progress Report, and solving u to the form given in equation (9′). The value of the coefficient k which fits the conditions of $u = 2600$ in equation (9′) is 1.29. If the resulting value of u differs from 2600 by 20 per cent, an error of 2 or 4 per cent in u may obtain. For other conditions of stiffness, distance between wheels, and weight of rail, a suitable average coefficient k may be calculated for use in place of 1.29 named above.

TABLE 21

Modulus of Elasticity of Rail-Support u—Tests on Chesapeake and Ohio Railway at Ashland, Kentucky

The values of u are given in pounds per inch per inch of one rail. Heavy load is 30,000 lb. on each wheel; medium load is 15,000 lb.

Location	From Summation of Rail Net Depression Ordinates		From Net Rail Depression at the Two Wheels Heavy Load
	Heavy Load	Medium Load	
1	2500	2000	3000
2	2900	2900	3100
3	2200	------	2400
4	2600	2400	2700
5	2600	2000	2900
Average	2600	2300	2800

The value of u obtained by using the average net rail depression at the two wheels in equation (9′) for each of the five locations for the heavy load, given in Table 21, is

somewhat larger than the corresponding value obtained by the use of the sum of the rail net depression ordinates. The average for the five locations is 2800 as compared with the average 2600 given in the table.

The method thus described may also be applied to the stretch of track for which rail depression at the rear wheel load was observed successively at 17 ties for the stretch of track just west of location 4 (see Fig. 63 for the net rail depressions) by substituting for y_1 in equation (9′) the individual values of the net rail depression at the rear wheel for y_1. The values so computed are recorded in Fig. 63 at each tie position. It is seen that the values have considerable variation, though of course the stiffness of the rail masks to a considerable degree the variability in the rail support. The values range from 1800 to 3000 and average 2400. Early in the tests the west portion of this stretch of track was seen to be less regular in play and general variability than in most other places along the track, and accordingly the stretch was chosen for the tie-to-tie load-depression test as track having marked unevenness in rail depression. The "hole" at tie 7 in the right hand portion indicates marked variability in the track.

Calculations of u have also been made by using the depression values obtained from levels taken on a point on the tie just outside the tie-plate. These values of u are somewhat larger than those obtained from levels on the rail, as may be expected from their not including the compression or detrusion of tie-plate into tie and because of the slight flexure of tie between rail and tack point. These data are useful in providing a check on the other data.

For the five locations at which track depression at one setting was measured, levels were also taken on both the north and the south rail at two ties between the wheels (the only position on the south rail readily usable for taking sights) in an effort to make some comparison of the stiffness of the track at the two rails. At one of these locations the data were found to be unreliable. For the four other locations the depression of the south rail at these ties was quite variable in comparison with the depression of the north rail just opposite, but the average at the south rail was about 8 per cent more than the average of the corresponding values of the north rail. However, the variability in the conditions along the track from point to point was such that the data are not considered conclusive. Rather it is believed that the stiffness of the track along the south rail was in general greater than that along the north rail, which is away from the other tracks. In the one test in which the load was moved from tie to tie and level readings were taken on the north rail at the rear wheel for every setting, level readings were also taken on the south rail at seven consecutive ties. In these the depression at the south rail averaged slightly greater than that at the north rail.

38. **Stresses and Moments in Rail.**—To get information on the variability of stresses in rail for uniform conditions of static loading, measurements of stresses in the two edges of both the north and the south rail were made immediately under the rear wheel of the heavily loaded car when over the middle of the width of the tie for every other tie at or including four of the five locations on which track depression tests had been made. Measurements of stresses at every tie would have been preferable, but the time available was too limited to permit increasing the testing work. The stretches of track used were considered to be representative of the general condition of the track except that at a point west of location 4 there was a low spot somewhat greater in length than was found elsewhere on the track. In each location is included a rail-joint on one rail for which of course no rail stress was measured.

In making the tests the car was moved from point to point and spotted over the middle of the gage line for which the reading was to be taken. It was found, as determined

by chalked places on the top of the rail, that the wheel bearing on the top of the north rail came at approximately the same place relatively to the width of the head at every test spot along the track and that the same regularity was found in the bearing position on the south rail, though the position on the two rails was not the same, and there was other evidence that the point of application of load by the wheels was essentially the same at all the points of test.

TABLE 22

Observed Stresses at the Two Edges of Base of Rail, Mean Stress, Ratio of Stress at Outer Edge to Mean Stress and Vertical Bending Moment—Locations 1, 3, 4 and 5—130-lb. R.E. Rail—Chesapeake & Ohio Railway

Load is 30,000 lb. on each wheel of four-wheel truck. Stresses are in pounds per square inch and moments in inch-pounds. Analytical moment is 260,000 inch-pounds.

Location		Series	North Rail					South Rail				
			Outer Edge	Inner Edge	Mean	Ratio Outer/Mean	Vertical Bending Moment	Outer Edge	Inner Edge	Mean	Ratio Outer/Mean	Vertical Bending Moment
1	Q	164	13700	5100	9400	1.46	238000	10500	11300	10900	.96	279000
	R	166	5900	22900	14400	.41	369000	7700	13500	10600	.73	272000
	S	168	7500	14500	11000	.68	282000	14900	8300	11600	1.28	297000
	T	170	10700	14500	12600	.85	322000	9100	11300	10200	.89	260000
	Opp. jt. 22	43						8100	12700	10400	.78	266000
	U	172	5300	17500	11400	.46	291000	3000	28800	15900	.19	406000
	V	174	16000	7400	11700	1.37	297000	3700	7700	5700	.65	146000
	W	176	4600	15800	10200	.45	260000	3500	18700	11100	.32	285000
	X	178	11900	5700	8800	1.35	226000	6100	7300	6700	.91	171000
3	Y	151	12200	12600	12400	.98	316000	7800	9000	8400	.93	213000
	Opp. jt. 26	131						1700	13700	7700	.22	195000
	Z	153	20500	7500	14000	1.46	359000	24800	7200	16000	1.55	412000
	a	155	20600	10400	15500	1.33	397000	16800	8600	12700	1.32	325000
	b	157	6200	7200	6700	.93	171000	2700	2700	2700	1.00	68000
	c	159	6000	400	3200	1.87	77000	5700	7700	6700	.85	171000
	Opp. jt. 27	140	4300	17700	11000	.39	282000					
	d	161	8300	20900	14600	.57	372000	9900	13700	11800	.84	303000
4	I	180	9900	11500	10700	.93	273000	7800	9000	8400	.93	214000
	J	182	12000	7400	9700	1.24	248000	9300	2500	5900	1.57	152000
	Opp. jt. 44	15						9600	8400	9000	1.07	232000
	K	184	12600	15200	13900	.91	356000	6900	18300	12600	.55	322000
	L	186	5100	13700	9400	.54	238000	4900	13500	9200	.53	235000
	M	188	4700	9300	7000	.67	180000	3300	19100	11200	.29	285000
	N	190	12100	3700	7900	1.53	201000	9100	6100	7600	1.20	195000
	Opp. jt. 45	110	6600	5800	6200	1.06	158000					
	O	192	9600	22600	16100	.60	412000	22600	11600	17100	1.32	437000
	P	194	6600	19800	13200	.50	338000	9200	5000	7100	1.29	183000
5	A	72	14400	10400	12400	1.16	316000	8800	9000	8900	.99	226000
	B	73	4800	21200	13000	.37	337000	5200	7200	6200	.84	157000
	Opp. jt. 47	22	6700	6900	6800	.99	173000					
	C	75	13000	4000	8500	1.53	217000	9200	10600	9900	.93	254000
	D	76	9500	15700	12600	.75	322000	7300	6500	6900	1.06	177000
	E	77	8300	9500	8900	.93	226000	6200	−4600	800	7.75	19000
	F	78	11300	5500	8400	1.35	214000	14300	18100	16200	.88	415000
	Opp. jt. 48	29						6400	6600	6500	.98	167000
	G	97	7300	13900	10600	.69	270000	18800	5600	12200	1.54	312000
	H	98	8900	11500	10200	.87	260000	10100	10300	10200	.99	260000
Average*			10000	11900	11000		279000	9300	10100	9700		248000

*Values at points opposite a rail-joint are not included in the averages.

The stress at the two edges of the base of rail developed with the heavy load and the mean stress in base of rail found by averaging the stresses at the two edges are given in Table 22 for the 30 places on each rail opposite to each other at which the stresses were observed and also the corresponding stresses at 7 places opposite rail-joints of these

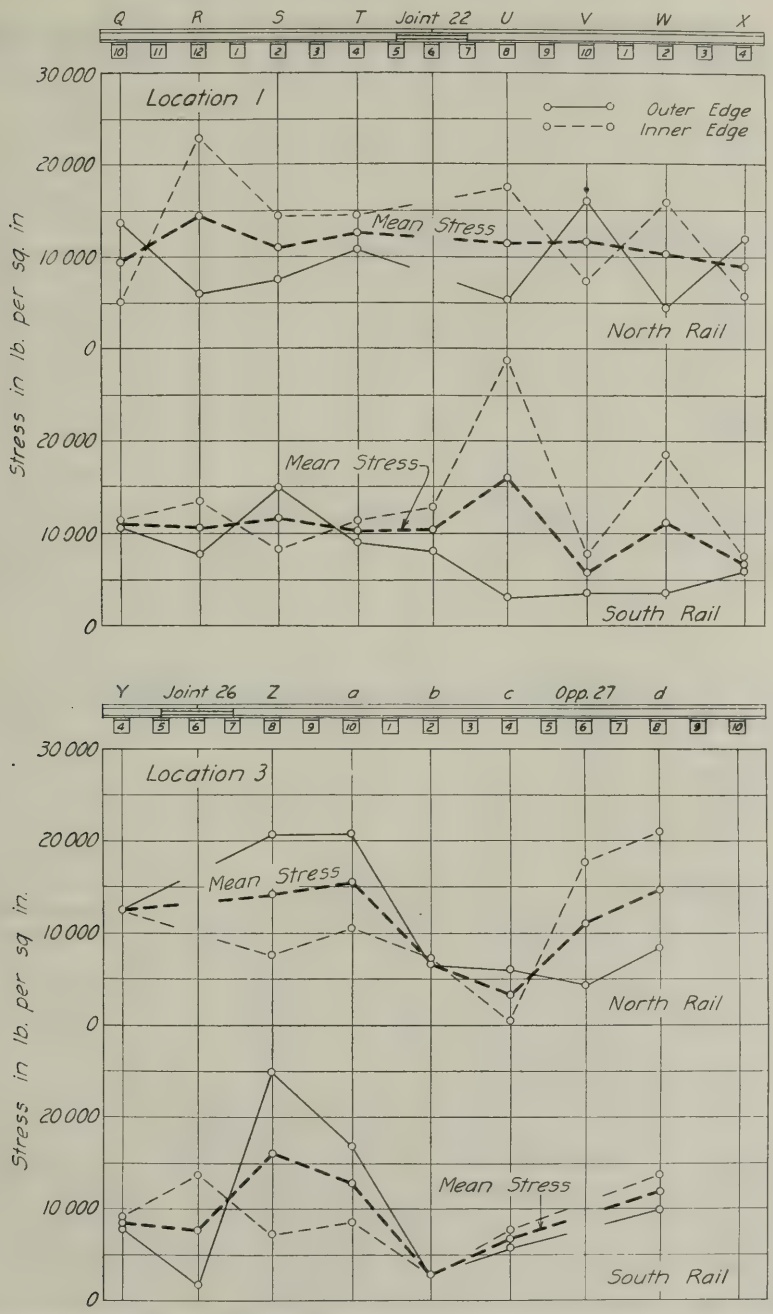


Fig. 70.—Stresses at Outer Edge and Inner Edge and Mean Stresses in Base of Rail at the Rear Wheel when the Load Is Moved from Point to Point—Locations 1 and 3—Tests on Chesapeake and Ohio Railway.

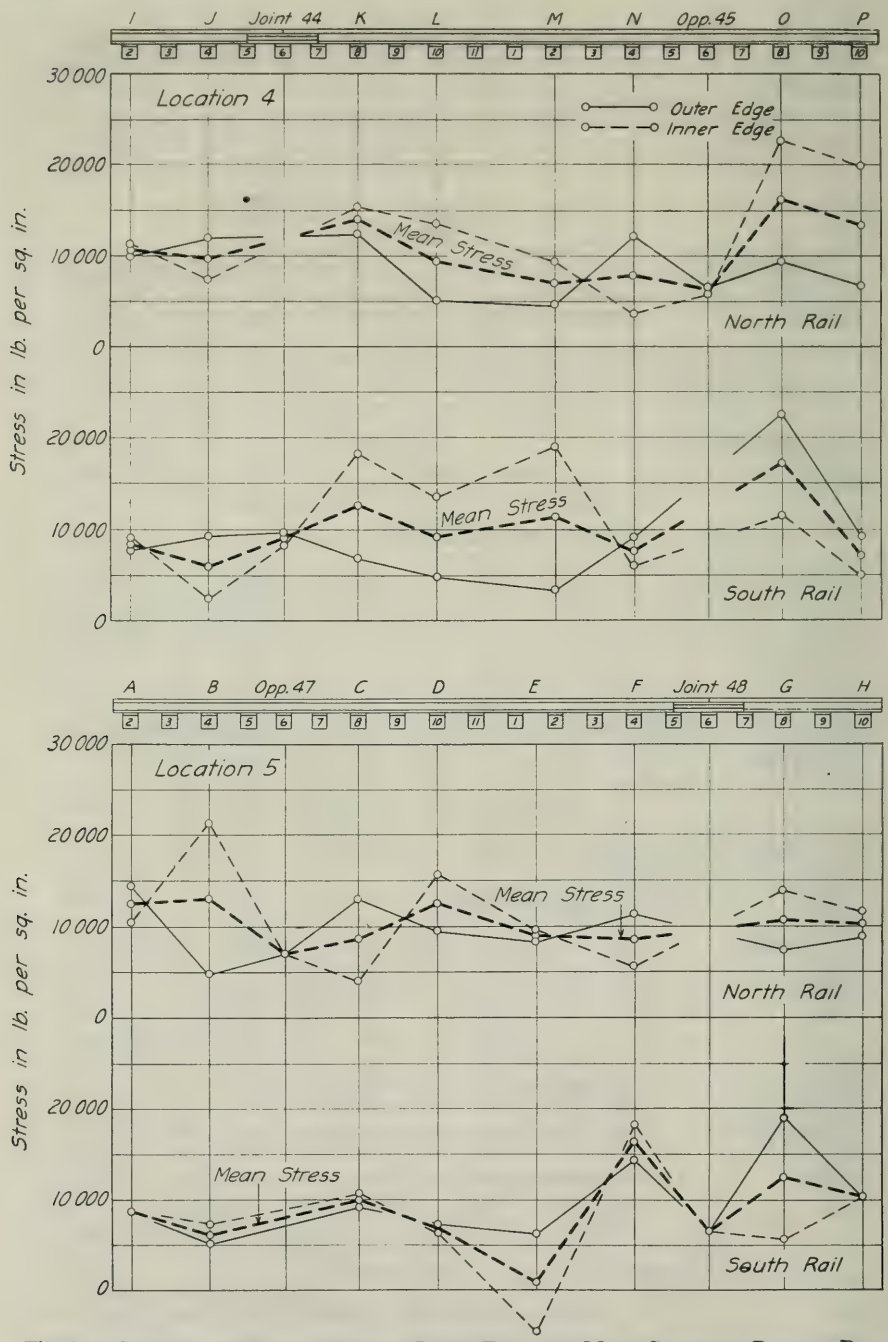


Fig. 71.—Stresses at Outer Edge and Inner Edge and Mean Stress in Base of Rail at the Rear Wheel when the Load Is Moved from Point to Point—Locations 4 and 5—Tests on Chesapeake and Ohio Railway.

stretches of track. The stresses at the outer edge and the inner edge of the base of rail given in Table 22 are plotted in Fig. 70 and 71 and the points are connected by fine full lines and fine dotted lines, respectively, and the mean stress in base of rail is also plotted and the points are connected by the heavy dotted line. The stresses given are for the bottom of the rail as reduced from the values measured at the two gage lines which were located on the upper surface of the rail flange .18 in. inward from the extreme edge and .53 in. above the bottom of the rail. In the reduction process, the mean stress at the level of the two gage lines (average of the observed stresses at the two gage lines) is multiplied by the ratio of the vertical distance between the horizontal geometrical axis of the rail section and the bottom of the rail to the vertical distance from the same axis to the level of the two gage lines (which ratio for the position of gage lines used was 1.21)—the result is the mean stress at the bottom of the rail. Half of the difference between the stresses at the two gage lines is the lateral bending stress at either gage line —positive at one edge and negative at the other. Since for the rail section the lateral bending stress remains the same at any given distance from the vertical axis, the lateral bending stress immediately below a gage line will be the same as that at the gage line. If the edge of the bottom of the rail is farther away from the vertical axis than is the corresponding gage line, a reduction is made by multiplying the given lateral bending stress by the ratio between the respective distances from the vertical axis to the edge of the base and to the gage line (1.06 in this case). This resulting lateral bending stress is then added to the mean stress at bottom of rail or subtracted therefrom to obtain the value of the stress at either edge of base of rail.

The averages of the mean stresses in base of rail developed with the heavy load at the various places at which stresses were measured in the four locations, excluding those opposite a rail-joint, (60 places in all), are given at the bottom of Table 22. The average of the stresses found in the north rail, 11,000 lb. per sq. in., is a little greater than the analytical value 10,200 lb. per sq. in. calculated with the average value of u (2600) found for the observed net depressions at the north rail. The observed mean stresses in the south rail are smaller than those in the north rail, their average (9700 lb. per sq. in.) being about 10 per cent less. Possibly a firmer condition of the ballast and tie beds at the south side of the track explains part of this difference in stress in the two rails. The ballast between track No. 1 and track No. 2 was fairly full between the tie ends and therefore the tie support at and near a tie end would naturally be firmer than that beyond the north rail where the shoulder sloped off in the way usually found at the outside of a track. However, the rail depressions on the south rail described in Article 37 "Values of Modulus of Elasticity of Rail-Support u" do not indicate that the support of the south rail is stiffer. Doubtless the differences in stresses are due mostly to the variations in rail support from point to point at the several locations.

Table 23 gives averages of the mean stress in base of rail with heavy load for each of the four locations and the average mean stress for the seven places opposite a rail-joint at these locations. Notwithstanding the great variation in stress from point to point the values of the average mean stress away from a rail-joint for the four locations do not differ greatly. The average of the mean stress opposite a rail-joint for the seven places included in the four locations is 8100 lb. per sq. in. This average is 79 per cent of the average of all the mean stresses away from a rail-joint in these four locations. If all 20 places at which stresses opposite a rail-joint are considered, the average mean stress is 8800 lb. per. sq. in., which is 86 per cent of the average of all the mean stresses observed at points away from a rail-joint. As the places away from the four locations include several low stresses in the north rail and high stresses in the south rail, the

values within the four locations seem more likely to be comparable and .79 a more probable ratio than .86. In either event, the stress and the moment developed in rail opposite a rail-joint average considerably smaller than those found at places away from a rail-joint. Here again the difference may be attributed to greater stiffness or less play just opposite a rail-joint than at points adjacent thereto.

TABLE 23

Averages of Mean Stress in Base of Rail for North Rail and South Rail at Locations 1, 3, 4 and 5—130-lb. R.E. Rail—Chesapeake and Ohio Railway

Load is 30,000 lb. on each wheel of four-wheel truck. Stresses are in pounds per square inch.

Location	North Rail		South Rail	
	No. of Places	Average Stress	No. of Places	Average Stress
Not at a rail-joint				
1	8	11,200	8	10,300
3	6	11,100	6	9,700
4	8	11,000	8	9,900
5	8	10,600	8	8,900
Average	30	11,000	30	9,700
Opposite 7 rail-joints in Locations 1, 3, 4 and 5	3	8,000	4	8,200
Opposite 20 rail-joints tested*	6	7,000	14	9,500

*The general average of stresses in rail opposite the 20 rail-joints is 8800 lb. per sq. in. and opposite the 7 rail-joints is 8100 lb. per sq. in.

TABLE 24

Direction of Lateral Bending of North Rail and South Rail at Thirty Places not opposite a Rail-Joint

Outward bending means bending of rail away from center of track and inward bending towards the center of track.

North Rail		South Rail		Combinations		
Outward	Inward	Outward	Inward	North Rail	South Rail	Number
11	19	11	19	Outward	Inward	7
				Outward	Outward	4
				Inward	Outward	6
				Inward	Inward	13

Stresses in rail were measured under both heavy and medium loads at points opposite 15 rail-joints (see Table 20). The stresses for the medium load (medium load is one half of heavy load) were not generally closely proportional to the ratio of the loads. At nine places the stresses with the medium load were greater than those corresponding to

the ratio of the loads. At four places the stress ranged from .82 to 1.00 times that developed with the heavy load at the same place. At one place the stress for the medium load was .34 of that with the heavy load. For the light load the stresses were still larger in comparison with those found for the heavy load. As noted in Article 26 it is evident that in places along the track the medium load gave stresses that are large in proportion to the ratio of the loads and at other places smaller stresses, according to the conditions of the individual tie supports at and near the loads.

A characteristic of the data recorded in Fig. 70 and 71 is the marked variation in stress and the quick change in stress from point to point along both the north rail and the south rail. It is seen that the greater stress is sometimes at one edge of the base of rail and sometimes at the other—changing from one side to the other and ranging from nothing at one edge to double the mean stress at the other—at one place showing a compressive stress of 4600 lb. per sq. in. at one edge, and at another place showing a tensile stress of 3000 lb. per sq. in. at the outer edge and 29,000 lb. per sq. in. at the inner edge, the latter stress being about three times the average of the mean stress in rail at all the points of measurement. At another place the stress was 7000 lb. per sq. in. at the inner edge and 25,000 lb. per sq. in. at the outer edge. These differences in stress at the two edges of the base of rail and the changes in position of maximum stresses indicate a constantly changing lateral bending of the rail from point to point, sometimes one way and sometimes the other, and also a marked twisting in the rail. Since the position of the wheel on the rail remained relatively the same for all the settings and since the bearing pressure of the wheel on the rail applied almost identical vertical and lateral loads statically at every spot, it is obvious that the variability and stress must be due mainly to the variations in the nature and position of the rail support given by the tie-plate, tie, and ballast just below the wheel and at the nearby ties in either direction.

The mean stress in base of rail shown by the heavy dotted lines in the figures may be considered as representative of the vertical bending moment developed in the rail from point to point. It will be seen that these mean stresses in base of rail vary greatly from point to point along the track, being at one tie 1.6 times the average stress along the track and at the second tie away only .1 times the average stress. These variations were obtained with the same load applied in the same way. With this great variation in stress and bending moment it is evident that there must be a great variation in the load carried by individual ties and in the position and direction of the supporting reaction applied to the rail by the tie-plate, tie and ballast bed.

As even the maximum stresses in the rail are not large, with a few exceptions, it may not be a question whether the rail is strong enough to take these twisting and lateral bending stresses, even though the effect of the variability of the reaction forces upon the motion of a moving train may be expected to increase the stresses at many points and to cause greater wear of wheels and rails than would be found in track developing greater uniformity in stresses, and though there is in addition the further effect of speed and imperfections of counterbalancing. The effect of the variability upon the tie and ballast bed, moreover, is of serious concern; it is evident that the variability in the direction and amount and distribution of bearing pressure on tie and ballast bed will greatly affect their wear, durability, and maintenance, and will have a great influence on the quality of the track surface and the cost of its maintenance.

The values of the vertical bending moment in both north rail and south rail are given in Table 22. The values are calculated from the mean stress in base of rail and are, of course, proportional to these stresses. It will be noted that the variation in the moments is very marked. It will be seen, too, that the moments in these two rails at

points opposite each other are sometimes alike and sometimes differ greatly. The highest values are 412,000 in.-lb. in the north rail and 437,000 in.-lb. in the south rail at points opposite each other, the latter being 1.8 times the average value at points on the same rail not opposite a rail-joint. At one point the moment in the north rail is 297,000 in.-lb. and in the south rail just opposite 146,000 in.-lb. The smallest value observed is 19,000 in.-lb.—here the stress in the outer edge is 6000 lb. per sq. in. tension and the inner edge is in compression. In Fig. 72 the magnitude of the vertical bending moments is plotted to scale in the order of the place in track for the four locations. In various ways the variability is striking.

In Table 22 is also given for both rails the ratio between stress at outer edge of base of rail and mean stress in base of rail. When the ratio is greater than 1, the lateral bending of the rail is outward from the center of the track; when less than 1, the lateral bending is inward. It will be seen that these ratios vary widely and quite irregularly.

The magnitude of the lateral bending moment in the rail may be calculated from the excess or deficiency of stress at the outer or inner edge of base of rail as compared with the mean stress in base of rail. The values so calculated for the north rail and the south rail have been plotted in Fig. 73. The outward lines represent values of the lateral bending moment when the rail bends outward from the center of the track and inward lines values when the rail bends inward. The values are plotted in the order in the track for the four locations previously described. In making comparison of the magnitudes of lateral bending moments with vertical bending moments it should be kept in mind that for the rail used the section modulus with respect to a vertical axis is .188 times that with respect to a horizontal axis. The greatest lateral bending moments measured are 41,000, 40,000, 62,000, 43,000, and 38,000 in-lb. The highest lateral bending stress was 13,000 lb. per sq. in. and this together with the vertical bending stress of 16,000 lb. per sq. in. makes the stress at the inner edge of base of rail 29,000 lb. per sq. in., as compared with the average mean stress in base of rail for all locations on the south rail of 9700 lb. per sq. in. In considering these lateral bending stresses and lateral bending moments it should be remembered that the method of static loading used did not include application of the lateral forces that may result from lateral swing or side thrust of locomotives and cars.

The direction of the lateral bending of the rail is of some interest. The summary of the direction of lateral bending given in Table 24 shows that for the 30 places of measurement each rail bent outward at 11 places and inward at 19 places. For the different combinations of lateral bending in the two rails at points directly opposite each other, the north rail bent outward and the south rail inward in seven places, outward and outward in four places, inward and outward in six places, and inward and inward in 13 places. Except for the differences in cant of the two rails, it is thought that the principal sources of the variations in lateral bending outwardly or inwardly are differences in conditions of rail support at and near the point of measurement, much of which is due to irregularities of tie-plate bearing.

With reference to cant of rail, the data of the tests show that although the inclination of the tie-plates was 1 in 28, the average measured cant of the unloaded north rail for 63 points at and near the various test locations was 1 in 27 and for 63 points of the unloaded south rail 1 in 16, the cant for each rail being fairly uniform throughout. The larger cant in the south rail may have been the main reason the wheel flange held close to the south rail in moving along the track, but it seems not to be a dominating influence in giving direction to the lateral bending. This canted rail has more points

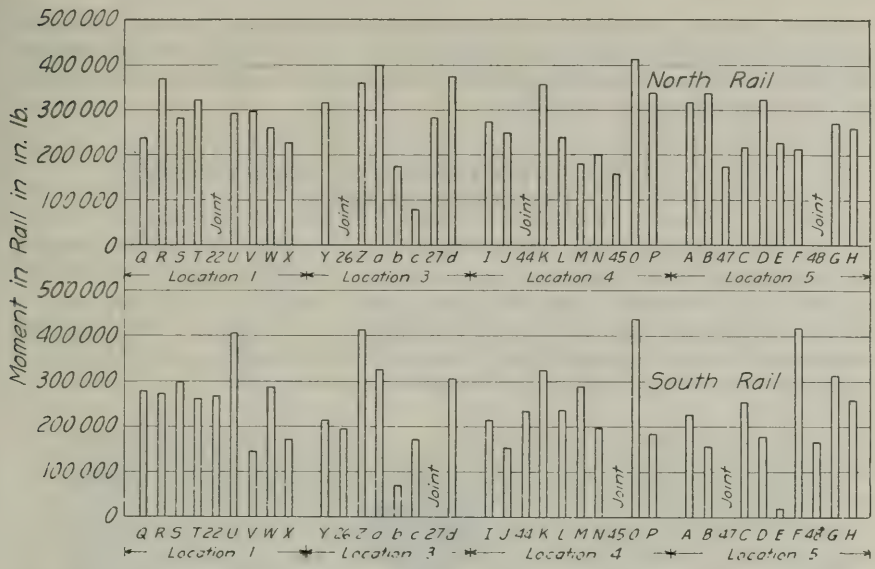


Fig. 72.—Vertical Bending Moment in North Rail and South Rail at the Rear Wheel when the Load Is Moved from Point to Point—Locations 1, 3, 4 and 5—Tests on Chesapeake and Ohio Railway.

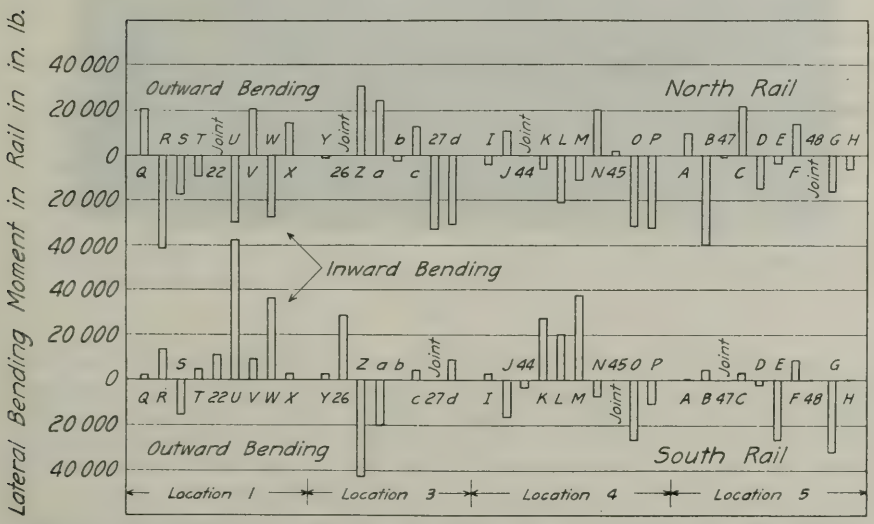


Fig. 73.—Lateral Bending Moment in North Rail and South Rail at the Rear Wheel when the Load Is Moved from Point to Point—Locations 1, 3, 4 and 5—Tests on Chesapeake and Ohio Railway.

of inward bending than outward bending and the average of the stresses at the inner edge of base of rail is greater than that at the outer edge, while tests of track with rail not canted have given more cases of outward bending than inward and greater average stress at outer edge than at inner edge.

VI. TESTS OF GEO TRACK ON THE MISSOURI PACIFIC RAILROAD

39. **Description of the GEO Track.**—The tests were made on the Missouri Division of the Missouri Pacific Railroad (on the line frequently called the Iron Mountain Route) at Middlebrook, Missouri 83 miles south of St. Louis, in October 1931. A stretch of GEO track about five and one-half miles long extending each way from Middlebrook was laid in December 1930. This is one of four locations on which this form of construction had been built by the Missouri Pacific Railroad.

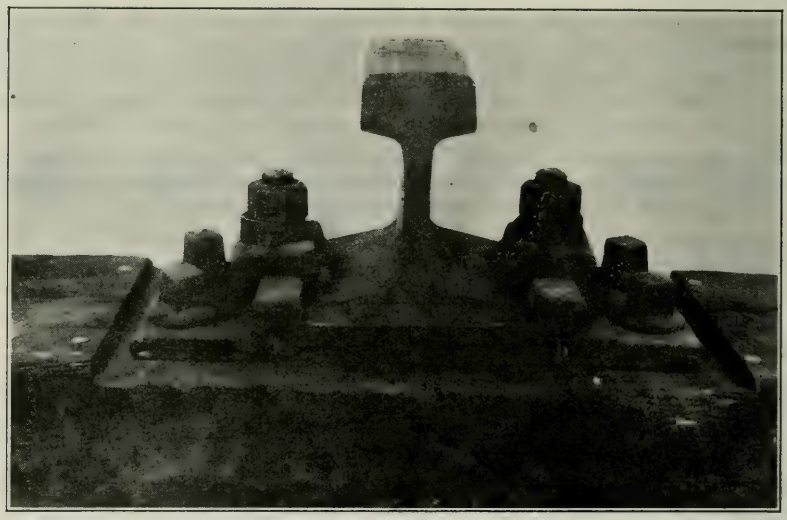


Fig. 74.—View of Rail, Tie-Plate, Tie and Fastenings—110-lb. R.E. Rail—GEO Construction on Missouri Pacific Railroad at Middlebrook, Missouri.

The main features of the installation of GEO track at Middlebrook may be described as follows (see Fig. 74). A heavy and stiff tie-plate having two heavy ribs or shoulders placed so that the base of rail closely fits in between is securely fastened to the tie by four screw spikes. On each side of the rail the outer leg of a U-shaped clamp rests upon the tie-plate outside the rib and a shorter and inner leg rests on the base of rail; a clamp bolt with its head lying in the slot of the rib at the middle of its length and reacting against the bearing face at the top of the slot has its nut tightened to hold the base of rail closely against the tie-plate. A coil spring washer was used under the nut of the clamp bolt. A creosoted poplar shim, compressed in its fabrication from a thickness of about .4 in. to about .2 in., and nearly filling the width between the ribs of the tie-plate and having a length greater than the width of the tie-plate lies on the tie-plate

and under the rail. In this installation the ties were preadzed and prebored by machines to receive the tie-plates and screw spikes; the tie-plates were fastened to the ties in the plant by a power wrench that applied a uniform torque to the screw spikes. The boring and adzing were such that the track gage and the cant of the rail, when the ties were placed in track and the rails laid on them, were not modified in the track-laying process. The application of the tie-plates in the shop in advance of track laying results in insuring more accurate fitting of tie-plate on ties and in providing more nearly uniform surface bearing of tie-plate on tie and in securing the desired cant of rail and uniformity of conditions from tie to tie along the track. Another advantage lies in that the tie-plate bearings at the two ends of the tie by the method of adzing are held in the same plane or in planes corresponding to the desired cant. At the same time the cant of the rail is kept the same in both rails throughout the length of track. In fact, except for the Delaware, Lackawanna and Western Railroad this track is the only track so far tested in which the specified cant (in this track, 1 in 40) remained closely uniform throughout. In this installation a special joint tie-plate 27¼ in. long extended over the two ties of a suspended joint, and the rail clamps and clamp bolts were placed at the side of the middle of the width of the ties next to the rail end.

The test locations were on fills of 4 to 8 feet, about seventy years old and wide, solid, and substantial. At the three test locations one and a half miles north of Middlebrook the ballast was hard, broken limestone free from fine particles and generally ranging from 1 in. to 2 in. in size. The ballast bed at these locations was unusually stiff. At the three locations one-quarter mile south of Middlebrook the ballast was flint gravel. It ranged from ¾ in. down and the sample examined contained 37 per cent of particles smaller than ¼ in. The limestone ballast well filled the spaces between the ties out nearly to their ends and the shoulders were wide and full. The flint ballast also was full between the rails, but the shoulders and slope were not so full.

The ties were treated oak ties (sizes 4 and 5 of standard sizes of American Standards Association), nominally 7 in. by 9 in. by 8 ft. The ties were unusually straight and uniform and well graded in size. Of 102 ties measured at test locations, 62 per cent had a width between 9 and 9¾ in., 22 per cent between 8 and 8¾ in., and 10 per cent between 10 and 10¾ in.—the remaining 6 per cent were narrower than 8 in. The spacing of the ties was unusually uniform. Away from the four ties at a rail-joint, of 128 ties measured 21 per cent were between 20 and 20¾ in. center to center, 32 per cent between 21 and 21¾ in., 30 per cent between 22 and 22¾ in., and 12 per cent between 23 and 23¾ in., the average spacing being 21½ in. The general spacing between the four ties at a rail-joint was 19 to 19¾ in.

The rail was 110-lb. R.E. laid in December 1930. The tie-plates were 7 by 14 in., with an inclination of 1 in 40 and no eccentricity.

The track in general was in excellent condition. It is reported that no maintenance work had been done upon it during the year it had been in service. The road is used principally for passenger service and not many freight trains are run over it, the heavy freight traffic being carried by another line.

40. **Method of Testing.**—Steel hopper coal cars of 70-ton capacity were used in the test. Two loads were used—(1) an unloaded car, (2) a car heavily loaded with coal. The loads on one end of the car were 26,200 lb. for the light load, and 105,400 lb. for the heavy load, which have been called 6500 lb. per wheel for the light load, and 26,500 lb. for the heavy load. For any test a rear wheel was spotted at the desired point midway between two ties (the rail fastening preventing measurement over a tie),

and the car was then moved successively from point to point along the rail. The stresses in rail were measured at the two edges of base of rail at gage lines ¼ in. above the bottom of the rail by means of a Berry strain gage of 2 in. gage length.* The Berry strain gage was used by a skillful and experienced operator and it is believed that the individual readings are generally accurate within 500 lb. per sq. in. Two engineer's levels and a special level rod 6 in. long graduated to one-hundredth inch and generally read to half-hundredths were used in getting the vertical movement between rail and tie-plate, tie-plate and tie, rail depression, and for other purposes. It is believed that under the conditions of the work these levels were accurate to one-hundredth inch. The readings of strain gage, levels, etc., were generally taken (1) at zero load (before the load was applied), (2) with the load in place, and (3) with the load removed (zero load).

41. **Tests of Track Depression.**—The method of determining the track depression involved taking levels along the track (1) with the track in an unloaded condition, (2) with the light car used as the load, (3) with a heavy car used as the load, and (4) again in an unloaded condition. The levels were taken with the pointed end of the special level rod (described elsewhere) placed in a punch mark on the base of the east rail near its outer edge over the middle of the width of each tie and in a punch mark on a nail in the tie about 1 in. away from the outer edge of the east tie-plate. For each test location these levels were taken at each individual tie from a position beyond the middle of the length of the test car to a tie about 17 ft. behind the rear wheel of the rear truck. Two engineer's levels were used, one opposite the front wheel of the rear truck and the other at a point of 10 ft. behind the rear wheel, each instrument being about 10 ft. from the rail. Check readings were taken on nearby benchmarks. To insure accuracy a second man is kept at the instrument to watch the level bubble. Levels on punch marks on a few tie-plates near the wheels of the rear truck were also taken.

To find the total vertical movement between the west rail and a nail on the tie about 1 in. beyond the outer edge of the tie-plate, for use in a comparison of the vertical movement of the two rails, a wooden bar placed over the top of the two rails carried at its west end an Ames dial having a plunger which rested on the nail in the tie; the difference in readings in the unloaded and the loaded conditions gave the value of the relative vertical movement between the west rail and the tie.

From the tests of track made previously, it is to be expected that the gross depression of rail caused by the application of a light load may be greater proportionally than that of a heavier load and that the added depression of the heavy load will in general be approximately proportional to the difference in the two loads. It is also to be expected that part of the depression found with a light load will be due to play existing between rail and ballast bed and hence should not be considered in determining the stiffness of the track.

In Fig. 75 and 76 the results of the gross depression measurements of rail and tie for light and heavy load for the six locations at which levels were taken are plotted as ordinates at each tie including seven ties at each end away from the two wheels of the car truck, and for convenience these points are connected by lines. The points on the dashed line at the upper part of each diagram (named the derived play curve) represent the play between the rail and the tie bed as found by subtracting from the gross depression with the light load a quantity found by multiplying the excess of the gross depression with the heavy load over that with the light load by the ratio that the excess of

* A reference to the Berry strain gage and its use is given in Article 6 "The Laboratory Tests of Rail-Joints."

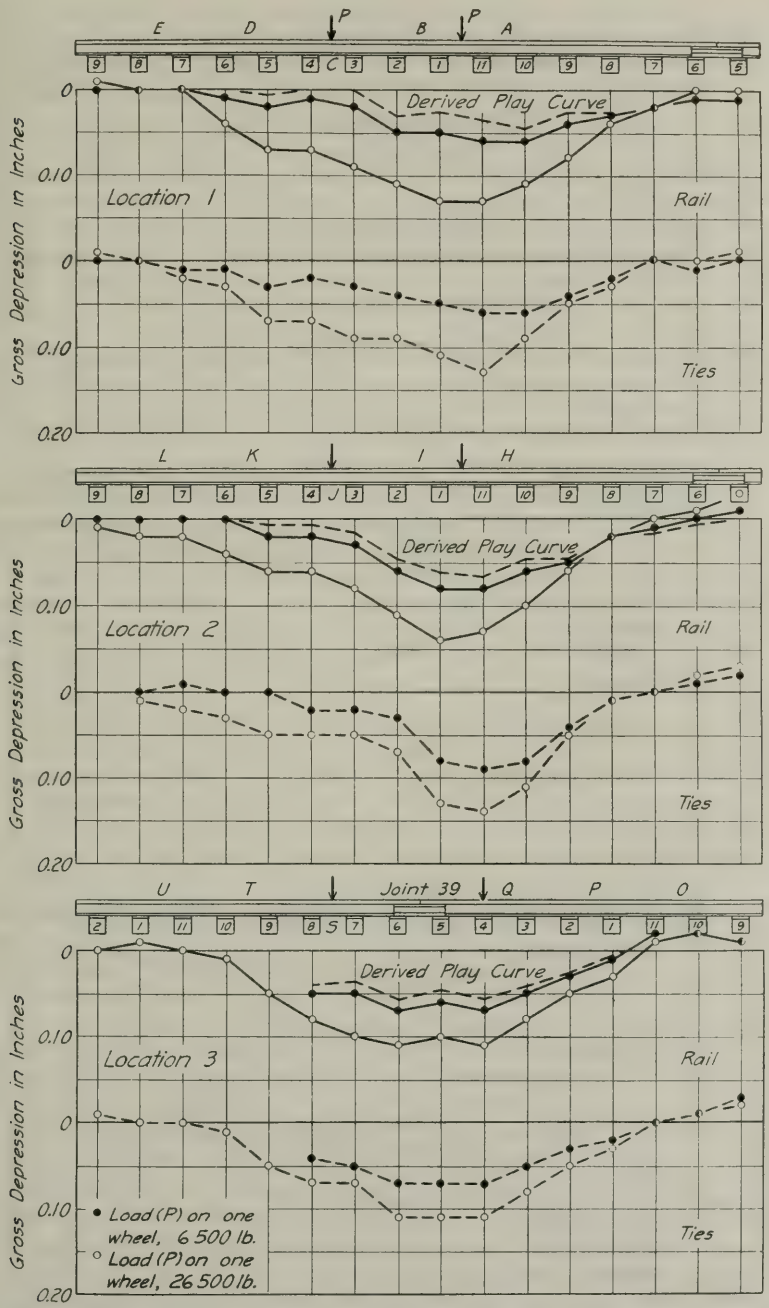


Fig. 75.—Gross Depression of Rail and Tie for Light and Heavy Loads and Derived Play Curve at Locations 1, 2 and 3—Limestone Ballast—Tests on Missouri Pacific Railroad.

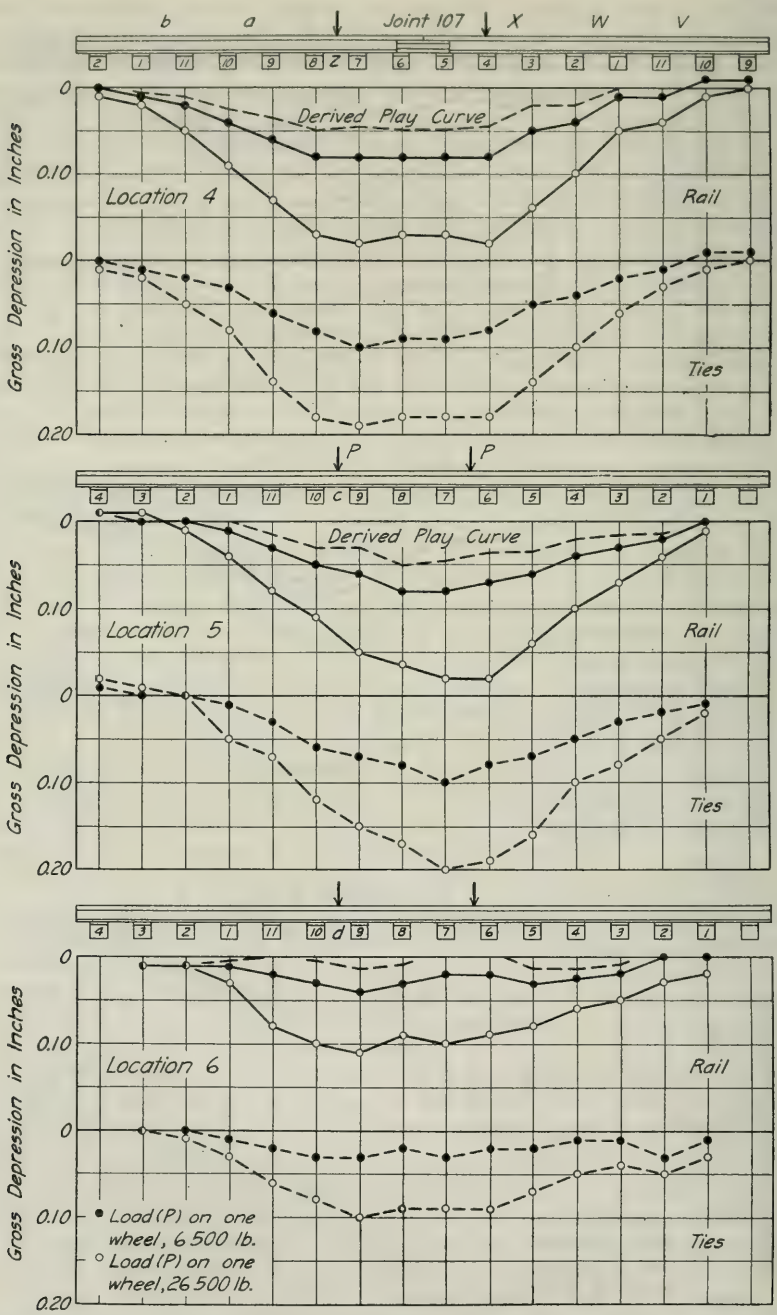


Fig. 76.—Gross Depression of Rail and Tie for Light and Heavy Loads and Derived Play Curve at Locations 4, 5 and 6—Flint Ballast—Tests on Missouri Pacific Railroad.

weight of the heavy load over that of the light load bears to the weight of the light load. This calculation is based on the assumption that the light load has brought both rail and tie to a firm bearing at each tie and that the further depression made by the heavy load is everywhere proportional to the added load taken by individual ties. It is possible that the light load may not have fully seated all the ties on the ballast bed, but except at ties near the end of the depression curve the ties adjacent to such unseated ties may take more than their share of load so that the average value of the rail depressions will not vary far from being representative of the average individual tie loads. At and near the ends of the depression curve the ties may not have taken much load, and in calculations their depressions may well be omitted from consideration. It should also be noted that upward movement of the rail and tie will not be representative of actual negative vertical pressures acting on the rail, as is discussed in Chapter V.

42. **Elements in the Total Rail Depression.**—The vertical movement between the rail and the tie's bed in the ballast may be considered to be made up of (a) play between rail and tie-plate, including any compression of the wooden shim by the applied load, (b) play between tie-plate and tie including any vertical movement of tie-plate due to imperfect bearing of tie-plate on the adzed surface, (c) compression of the tie throughout its depth when load is applied through the tie-plate, and (d) play between bottom of tie and its ballast bed including any bending of the tie to reach the bed directly under the rail. Below the tie, there will be a vertical depression of the ballast and roadway, which of course will vary according to materials and conditions. No comprehensive tests were made to determine precisely the value of the several parts referred to, but the following statements give an idea of the distributions of the vertical movements as judged from the measurements and observations made in the field.

(a) The compression of the wooden shim (which in its fabrication was compressed to half its original thickness) is minute—probably less than can be told with the scale of the measurements taken; its usefulness may be expected to be due principally in overcoming roughnesses of metallic surfaces and in avoiding movement of metal on metal, with perhaps some resulting adjustment in the bearing from side to side of rail base by differences or changes in thickness of the shim at the two edges with time. The total vertical movement between rail and tie-plate was generally hardly measurable, probably usually less than .01 in. In 28 places measured in four test locations, the play between rail and tie-plate, as found after the heavy load was applied, was approximately .01 in. at 3 ties, .02 in. at 5 ties, and .03 in. at 1 tie. This freedom from much vertical movement between rail and tie-plate is to be expected with the form of rail clamp used. It was observed that rail clamps were slightly loose at two ties on the test locations.

(b) The play between tie-plate and tie was also generally very small. At 4 ties out of 28 a play of .02 in. was observed at the east rail on the application of the heavy load and a play of .01 in. at 4 ties. On the west rail, at the same test locations, the vertical movement between rail and tie, as measured by a dial gage, was .02 in. or more at 6 ties out of 38. It was evident that the method of preadzing employed and also the method of holding the tie-plate against the tie with screw spikes generally resulted in full bearing and lack of play at most of the places where measurements were made. In a few ties away from the test locations used, imperfect tie-plate bearings were found for part of the length of a tie-plate and a thickness of paper could be inserted under the tie-plate for a few inches or the edge of a shovel for a short distance. Altogether, however, the tie-plate bearings were far superior to the usual conditions found with ordinary track spiking or even with the best driven spiking of tie-plate to tie.

(c) Little definite information is known on the amount of elastic compression produced in the tie through its depth by the tension retained in the screw spikes after a period of time and the consequent reduction in the amount that the tie would otherwise be compressed when its load was applied. It seems probable that part of the original squeezing of the tie when the screw spikes were applied at the fabricating plant had been lost and the elastic part that remains will vary from tie to tie. Perhaps the average compression upon application of the test load, judging from a few laboratory tests, was of the order of .01 in. or .02 in.

(d) As reported elsewhere the play between tie and ballast bed ranged from 0 to .14 in. The total play or looseness between rail and tie-plate, tie-plate and tie, and tie and ballast bed ranged from .01 to .16 in. These values do not include the amount the tie is compressed by an applied load.

43. **Vertical Play or Looseness between Tie and Ballast Bed.**—One of the purposes of the tests was to learn what vertical play or looseness may exist between tie and ballast bed at individual ties, both when the rail clamp is fastened and when the fastening is released; that is, to determine whether there were "hanging" or "suspended" ties or whether all ties remain on their ballast bed when the rail is in an unloaded condition. The method used was to take levels accurately on a nail inserted in the tie about 1 in. away from outer edge of the tie-plate, as heretofore described. The level readings were generally made at the east rail only, though in some cases readings were taken at both ends of the tie.

The first readings were taken with the rail clamp fastened with its original tightness. The two rail clamps at one end of the tie were then loosened and level readings taken on the nail. A bar was then placed under the rail head and over a fulcrum block resting on the tie beyond the gage side of the rail and downward pressure was exerted by a man at the end of the bar. The resulting pressure on the tie (probably between 500 and 1000 lb.) was sufficient to seat the one end of the tie on its ballast bed or at any rate to hold it very nearly at that position. Level readings were again taken. It was found from other measurements that the fastening of rail to tie-plate at the further end of the same tie was not rigid enough to affect the movement of the tie at the test end. This was evidenced by results obtained on certain ties by also loosening the rail clamps at both ends of the tie. The foregoing test is termed the push-down test.

Following the push-down test the pull-up test was made by inserting the bar through ballast under the end of the tie, using a short block as a fulcrum, and applying suitable pressure at the further end of the pry. Pressure was exerted at the end of the pry until the rail and tie-plate and rail were surely in contact, and level readings were again taken on the tack 1 in. outside the tie-plate. Any difference between the level reading referred to and the one taken before the rail clamp was released would indicate a movement between tie and rail. Of course a lift of the rail would be detected by a decreased level reading.

It was found in most cases that upon loosening the rail clamps and releasing their hold the tie dropped somewhat until it was supported at some place on the ballast bed. In Table 25 are given in the fourth column the amount of the drop of the tie upon release of the rail clamps at test locations 1, 2, 3 and 4. Observations were made by push-down tests on 35 ties at the test locations used. In 10 ties no vertical movement of the tie was observed upon release of the fastening, 11 ties

dropped .01 or .02 in., 6 ties dropped .03 to .05 in., 6 ties dropped .06 to .09 in., and 2 ties dropped .10 in.; 14 of the 35 ties then showed a play between .03 and .10 in. It is apparent then that many of the ties may be classed as "hanging" ties and that for these ties and the stiff ballast support the rail in many cases must depress an

TABLE 25

Vertical Play or Looseness between Tie and Ballast Bed—Tests on Missouri Pacific Railroad at Middlebrook, Missouri

Values are given in inches.

Test Location	Ballast and Rail	Tie Number	Drop of tie on release of rail clamp	Drop of tie plus push-down
1	Limestone ballast East rail	10	.03	.05
		11	.08	.08
		1	.01	.02
		2	.00	.00
		3	.01	.01
		4	.00	.01
		5	.01	.01
2	Limestone ballast East rail	11	.10	.11
		1	.09	.10
		2	.00	.02
		3	.00	.00
		4	.00	.00
		5	.03	.05
		6	.06	.07
3	Limestone ballast East rail	2	---	.00
		3	---	.02
		4	.01	.02
		7	.01	.02
		8	.03	.04
		9	.01	.02
	West rail	6	.04	.05
		7	.01	.03
		8	.06	.08
4	Flint ballast East rail	10	.05	.07
		11	.05	.07
		1	.06	.07
		2	.01	.01
		3	.02	.03
		4	.00	.00
		7	.00	.00
		8	.00	.00
	West rail	10	.10	.14
		11	.07	.12
		11	.02	.02
		1	.00	.00

amount equal to a considerable proportion of the net depression of the track before individual tie bearings will permit loads to be carried by such ties. It may be noted that there appears to be little difference in the proportional number of ties having the different ranges of drop with the two kinds of ballast for the locations on which observations were made.

The push-down test at the same ties, made after the rail clamps were loosened, indicated whether the tie had reached its normal bearing bed before the push-down test was applied. In the last column of Table 25 is given the total movement of the tie including the drop and the push-down movement. For about 40 per cent

of the ties tested no further vertical movement of the tie was found on application of the push-down test; these ties had already dropped to the bearing bed. The other ties were forced down a small distance, usually .01 or .02 in., but sometimes .04 or .05 in. The greatest value of drop plus push-down was .14 in. In general, however, the releasing of the rail clamps permitted the tie to assume its normal bearing bed or to come within a small distance of it.

The pull-up test, as generally carried out, showed the relative position of the tie with respect to the rail after the push-down and pull-up tests had been applied and in some respects was a check on the observations. In 26 out of 35 ties the results indicated that the tie came back to its original position with respect to the rail or closer or that the rail was lifted slightly. In 8 of the 35 ties the pressure applied did not bring the tie within .01 in. of the original height; 1 tie remained .02 in. low. In these few cases either the lifting of the tie was obstructed or some slight inaccuracy developed.

The ties included in the push-down and pull-up tests were chosen at the locations where stresses in rail had been measured and load depression tests made. Time was not available to make observation on all ties in the test locations.

In Table 26 is recorded the vertical play or looseness for ties 10 and 11 at location 4 (flint ballast) — two hanging ties. For these ties the rail clamp on one rail was first loosened and level observations made at the tack outside of each rail and at the tack at the middle of the length of the tie, and observations were also made with the rail clamps on both rails loosened. The observations were made after the tie was free to drop and also after the push-down test had been applied. The greatest amount of drop for tie 10 with clamps of both rails loosened was .05 and .10 in. for the two end points and .05 in. for the middle point, and for tie 11, .05 and .07 in. for the two end points and .05 in. for the middle. It is seen that both ties were hanging ties. It is apparent from the data that the two ties tilted or rocked about their middle when pressure was applied at either end of the tie and that the ties were center-bound.

There were further evidences that the tie bearings partake of the center-bound condition in the locations on flint ballast. For four consecutive ties which came at or between the two wheels of the end truck of the loaded car when the load depression test had been made at location 5, the depression at nails inserted in the extreme end of the tie was greater than the depression of the nail close to the outer edge of the tie-plate by .005, .015, .01, .025 in., respectively. On all locations on the flint ballast (see Fig. 76) the depression of the tie in the static load tests was in general greater just outward from the tie-plate than those measured at the rail. Other observations also indicated that many ties were in a center-bound condition and that the part of the ties outside of the rails did not transmit to the ballast its full share of the tie load and that there was evidence of looseness at the tie end.

44. **Variation in Load Taken by Individual Ties.**—In Fig. 75 and 76 is also plotted the derived play curve of the rail with respect to the ballast bed found on the assumption that the light load seats the tie on its ballast bed except near the ends of the depression curve and that the net depressions of the light and the heavy loads are proportional to their weights. The values of the derived rail play with respect to the ballast bed in the case of the limestone ballast, throughout the length of the depression curve on which the tie may be expected to be brought down to full ballast bed bearing by the light load, as recorded in the figures, ranged from 0 to

TABLE 26

Vertical Play or Looseness between Tie and Ballast Bed at Two Ties at Location 4 on Flint Ballast—Tests on Missouri Pacific Railroad at Middlebrook, Missouri

Values are given in inches.

Condition of Rail Clamps	Condition of Tie	Vertical Drop of Tie		
		East Point	Middle Point	West Point
Tie 10				
Clamps of east rail released	Free	.05	------	------
	Push-down applied at east rail	.07	------	------
	Free	.05	.03	.02
	Push-down applied at east rail	------	.03	------
Clamps of both rails released	Free	.02	.04	.06
	Push-down applied at west rail	.01	.07	.14
	Push-down applied at east rail	.05	.06	.10
	Free	.04	.05	.10
	Push-down applied at east rail	.06	.05	.10
	Push-down applied at west rail	.02	.05	.11
Tie 11				
Clamps of east rail released	Free	.05	.02	—.02
	Push-down applied at east rail	.07	.03	—.02
Clamps of both rails released	Free	.02	.05	.07
	Push-down applied at west rail	.00	.06	.12
	Push-down applied at east rail	.04	.05	.07

.06 in. It will be seen from an examination of the diagrams that there is considerable variation in the amount of this play between rail and ballast bed at different ties in the same vicinity. For example, for location 2 at ties 3 and 4 there is little play, while at ties 11 and 1 the play indicated by the levels is .06 in. Further, in the case of location 2, where the drop of tie found when the rail clamps were loosened had total values at ties 11 and 1 of .11 and .10 in. (see Table 25), it is evident that ties 11 and 1 under the heavy car must be taking no more than 30 and 50 per cent of the proportionate share of the load that would be expected to be carried by them. Besides, it is obvious that this deficiency in the vertical support (or upward pressure) given by these ties will result in increased stresses in the rail in the neighborhood of ties 11 and 1, as is pointed out in the discussion of the stresses along the rail for location 2. Conversely, considering the lack of play at ties 2, 3, and 4 which lie between the two adjacent spots (that is, between ties 11 and 1, and ties 5 and 6), by similar reasoning from the play and the drop observed the upward pressure taken by these three ties (11, 1 and 5) is roughly 30, 50 and 20 per cent of their proportionate share, respectively, so that ties 2, 3 and 4 carry perhaps twice the share they would carry if the ties had uniform supporting value, and

consequently the moments and stresses developed at ties 3 and 4 (spot J) were only about 40 per cent of normal value, as is seen from the data of stress measurements given elsewhere. Similarly at location 1 at ties 3 and 4 the play between rail and tie bed is 0, while at ties 10 and 11 the play is .04 in. Variations in tie load must result at ties in the neighborhood of ties 10 and 11, just referred to, where the drop of tie when the rail clamps were released was .05 and .08 in., these values being greater than the ordinate of the derived play curve.

In the case of the flint ballast, at location 4 the derived play curve of the rail with respect to the ballast bed was quite uniform, the ordinate being about .05 in. through most of the central portion of the length of the depression curve. At ties 10, 11 and 1 at the right side of the diagram the tie drops upon loosening the rail clamps were .07, .07, and .07 in.; these values are greater than the total rail depression at these ties for the heavy load and hence they carried no load. If the wheels had been directly over or near these ties they would probably have carried 80 per cent of their calculated share of load. In location 5 the derived play was fairly uniform, about .03 to .05 in. The rail clamps were not loosened, but the greater total net depression in the vicinity of ties 6 and 7 (see Fig. 76) indicates that ties 6 and 7 would have given large drops and that these two ties did not take their share of load. At location 6 the vertical play of the rail was very small, in general 0 or .01 in. Although tie drops were not taken it is probable that there was a fairly proportional distribution of load among the ties as compared with the other locations.

45. **Values of Modulus of Elasticity of Rail-Support u.**—The meaning of the term modulus of elasticity of rail-support u and the method of computation of values derived from data from tests have been discussed in Article 37 "Values of Modulus of Elasticity of Rail-Support u" for the tests on the Chesapeake and Ohio Railway. The method used for determining u from the tests on the Missouri Pacific Railroad is the same except that data for pull-up and push-down tests are not generally available for the stretches along the test locations on which load-depression tests were made. For the main part of the depression curve between wheels and next to them, as in the Chesapeake and Ohio Railway tests, the rail net depression curve for the heavy load may be expected to represent the average vertical resistance to downward movement (tie load proportional to the ordinate). If at any tie along this length the light load did not bring the tie to a fair bearing on the ballast bed, another tie or ties will usually have carried a greater proportion of load to make up for the discrepancy. For a short distance at the ends of the net depression curves a small estimated allowance for the effect of play (in this case mostly between tie and ballast) has been made for the ties that obviously have not carried full load.

In Fig. 77 the rail net depression ordinates for the six locations, obtained by subtracting from the ordinate of the gross rail depression curve for the heavy load the corresponding ordinate for the derived play curve, have been plotted for the ties that are considered to carry load. Beyond these ties light dotted lines connect ties that are not considered to carry full proportionate load. The rail depression at the individual ties found from the ordinates of the net depression curve may then be summed for the length referred to. The value of the modulus u is then calculated by dividing the total weight on the two wheels of one rail by the product of the average tie spacing and the sum of the net rail depression at each tie so found. Table 27 gives in one column the values

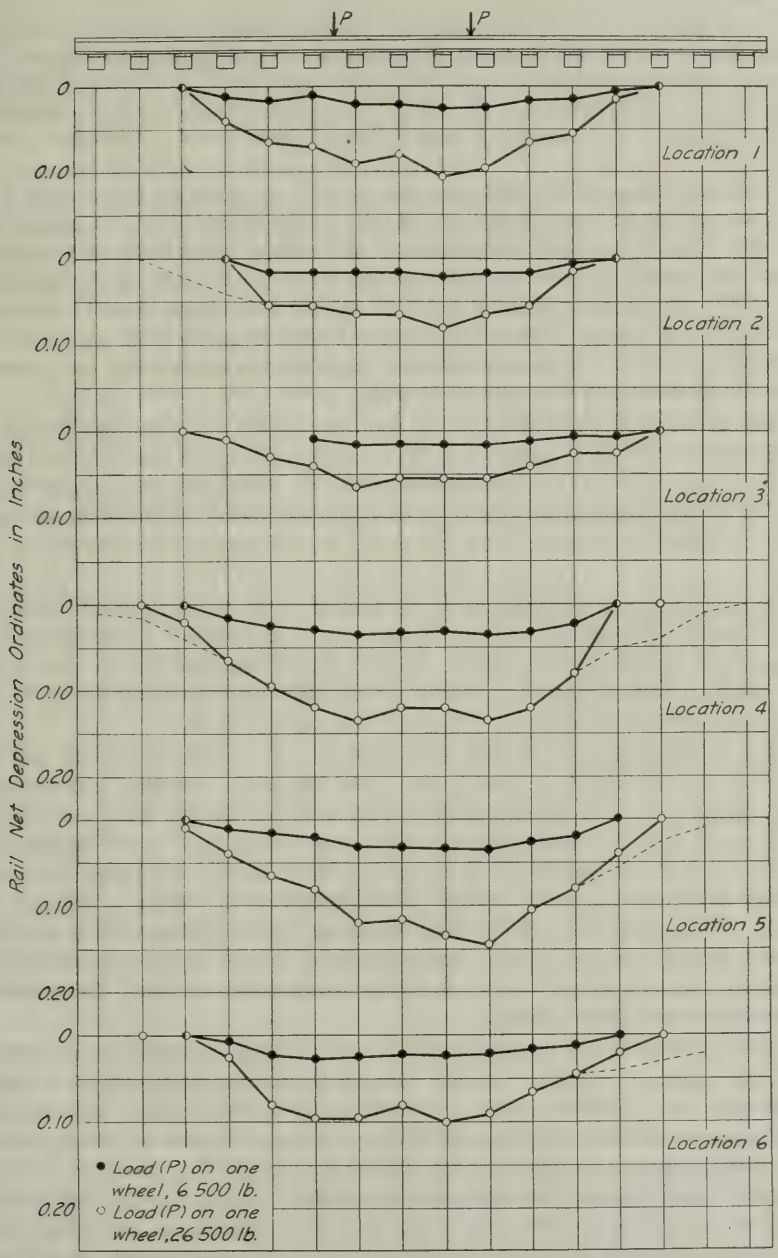


Fig. 77.—Rail Net Depression Ordinates for Light and Heavy Loads at Locations 1, 2 and 3 (Limestone Ballast) and Locations 4, 5 and 6 (Flint Ballast)—Tests on Missouri Pacific Railroad.

of the modulus u for the three test locations on limestone ballast and the three on flint ballast by the method that uses the summation of net rail depression ordinates. The values on the limestone ballast (3700, 5500, 6200, average 5100) are extremely large and represent a very high stiffness in the track. The modulus for the track on flint ballast (2500, 2600, 3600, average 2900) showed a less stiff track but the values of u are still quite high.

A striking feature of the track depression tests on the limestone ballast, then, is the small value of the net track depression and the consequent high stiffness of the rail support and the correspondingly large value of the modulus of elasticity of rail support found. At location 1 the net depression of the rail at the ties between the wheels and just outside for the heavy load averaged .09 in., the value being given to the closest hundredth. For location 2 the net depression for the corresponding ties was .06 in., and for location 3, .05 in. These are extremely small net track depressions for a load of 26,500 lb. on each wheel of a four-wheel truck.

For the track on flint ballast the net depression of the rail at the ties between the wheels and just outside averaged .12 in. for location 4, .12 in. for location 5, and .09 in. for location 6. These may be compared with net rail depressions under similar loading reported in the First Progress Report for track on the Illinois Central Railroad having limestone ballast, which ranged from .20 to .40 in. and gave an average value of u of 1200.

It is apparent that the fastening of the tie-plate to the tie in a manner that largely retains the initial compression of the tie decreases the compression of the tie itself occurring when a wheel load is applied. This is evidently one source of the greater stiffness found on both the limestone ballast and the flint ballast in comparison with that observed on track not having the tie-plates so fastened to the tie.

It is apparent that with the stiff support given by the substructure on the limestone ballast (by far the stiffest track yet tested by the test party) seemingly small variations in conditions from point to point produce hard spots and less stiff spots that result in unevenness in net track depression which has a considerable effect on the uniformity of the track surface. It would appear, too, that the hard spots in this ballast will not be pounded down much under heavy traffic as compared with the change in elevation produced on the less stiff spots. It is evident, then, that for such ballast methods of spreading and tamping should be devised and employed to produce a more uniform stiffness of support along the track than is frequently or generally obtained. This matter is discussed further in Chapter VIII.

In the case of the flint ballast (which was more regularly graded from the fine to the larger particles and had considerable fines but no particles larger than ¾ in. and in which many of the particles above ½ in. could easily be broken into smaller particles) tamping was more easily done and uniformity of play and bearing on ballast could be more easily attained, though, of course, it is to be expected that this ballast will not withstand heavy traffic as will the broken stone ballast used in the other test locations. The lesser stiffness of the flint ballast layer because of the amount and nature of the fine material, resulting in greater track depression and in a smaller value of u, permits greater variation in play from tie to tie without resulting in a relatively higher variation in stress in rail found with the high stiffness of the limestone ballast. The relative resistance of the two ballasts to retention of track surface under heavy traffic with time

is another question. It is to be expected, of course, that the limestone ballast will better stand the test of heavy traffic. The source of the difference in stiffness and ease of tamping need not be taken up here. In the flint ballast, the end of the ties appeared less well supported than was the case with the limestone ballast, and there was an appearance of pushing out or shaking down of the flint ballast beyond the ends of the ties and at their edges (which might contribute to a center-bound tie condition) although the shoulders were wide and full all along the track.

A further comment on effects of play on the quality of track may be made. The play between rail and ballast bed at location 3 on the limestone ballast for 6 ties at and near the wheels averaged about .05 in. and was quite regular in amount. It would seem that the corresponding value of u (6200) is probably representative of the value of u on the limestone ballast when the play is uniform along the length of the wheel base and the drop of tie on release of rail clamps is small. At location 2 the value 5500 assumes that all the ties except at the ends of the depression curve have taken their proportional share of load. The value at location 1 (3700) although smaller shows very stiff track. The average value of the modulus for the three locations (5100) indicates extremely stiff track, by far the stiffest yet tested. On the flint ballast, location 6 was quite stiff but locations 4 and 5 although stiffer than most track were lower in stiffness. The average value for the three tests on flint ballast is 2900. The values 5100 and 2900 may be considered to represent the relative stiffness on the two kinds of ballast on this track.

It may be of interest to call attention to the comparative values of the net track depression at the wheels of these heavily loaded cars corresponding to the moduli just given. For the limestone ballast the value of y_1 (rail depression under one of the four wheels of a truck carrying 106,000 lb.) for a modulus of 5100 is .08 in. and for 2900 is .13 in. When the track depression is so very small, it is apparent that the presence of uneven play among the ties and especially the presence of tie drops that will result in uneven distribution of load on nearby ties, if such play and unevenness exists in the track, may have an extreme effect on stress variation in rail from tie to tie and that the effect of variation in play and stiffness will be very marked in very stiff ballast. In other words in very stiffly ballasted track there is a greatly increased need of uniformity of track support, with the alternative of greatly increased variability in stresses and great variations in tie pressures from point to point along the track.

It should be noted that if u were calculated from gross rail depression the values would be 25 to 40 per cent smaller than those given in the table. As the play involved in the gross depressions furnishes no appreciable resistance to load, values calculated from them should not be considered when u is to be used in calculating analytical stresses and depressions.

In the last column of Table 27 are given values of u calculated from the average net rail depression at the two wheels on one rail by the use of equation (9′) (see Article 37). For the conditions of these tests the values of k are smaller than for the tests on the Chesapeake and Ohio Railway. The calculated values of k for these tests vary from 1.20 for a value of u at and near 3000 to 1.05 for a value at and near 6400. As in the tests on the Chesapeake and Ohio Railway, the values obtained by this approximate method are larger than are found from the summation of net rail depressions. For the very stiff track the influence of a second wheel on the rail depression at a first wheel is small, and

also the measured depression outside of the two wheels is relatively greater than the analytical value as compared with the differences in less stiff track, so that it may be said that the stiffer the rail support the greater the difference in the values found by the two methods. This is shown by the results in the last column of Table 27.

TABLE 27

Modulus of Elasticity of Rail-Support u—Tests on Missouri Pacific Railroad at Middlebrook, Missouri

The values of u are given in pounds per inch per inch of one rail. The load was 26,500 lb. on each wheel.

Location	Ballast	From Summation of Net Rail Depression Ordinates	From Net Rail Depression at the Two Wheels
1	Limestone	3700	4300
2	Limestone	5500	6400
3	Limestone	6200	8100
Average		5100	6300
4	Flint	2500	2900
5	Flint	2600	3100
6	Flint	3600	4300
Average		2900	3400

46. **Stresses and Moments in Rail.**—To get information on the variability of stresses in rail along the track, measurements of stresses in both the east and west rail were made at the two edges of the base of rail immediately under the rear wheel of the heavily loaded car (26,500 lb. per wheel) with this wheel at the mid-point between ties for points located at every other tie spacing for three locations on the limestone ballast and one location on the flint ballast. Lack of time prevented taking measurements at every tie space and at the two other locations on the flint ballast. The stretches of track used were considered to be representative of the general condition of the track. In each location was included a rail-joint on one rail for which of course no rail stress was measured.

In making the tests the car was moved slowly from point to point and spotted over the middle of the gage line for which the reading was to be taken. Observations showed that the wheel bearing at the top of the east rail came at the same place relatively to the width of the head at every test spot along the track and that the same regularity was found in the bearing position on the west rail, though the position on the two rails was not the same, and there was other evidence that the point of application of load by the wheels was essentially the same at all the points of test.

The stress at the two edges of the base of rail developed with the heavy load and the mean stress in base of rail found by averaging the stresses at the two edges are given in

TABLE 28

Observed Stresses at the Two Edges of Base of Rail, Mean Stress, Ratio of Stress at Outer Edge to Mean Stress, and Vertical Bending Moment—Locations 1, 2 and 3 Limestone Ballast, Location 4 Flint Ballast—110-lb. R.E. Rail—Missouri Pacific Railroad

Load is 26,500 lb. on each wheel of four-wheel truck. Stresses are in pounds per square inch and moments in inch-pounds. Analytical moment for limestone ballast is 185,000 in.-lb. and for flint ballast 208,000 in.-lb.

Location		Series	East Rail					West Rail				
			Outer Edge	Inner Edge	Mean	Ratio Outer/Mean	Vertical Bending Moment	Outer Edge	Inner Edge	Mean	Ratio Outer/Mean	Vertical Bending Moment
1	A	2	10700	10700	10700	1.00	215000	11400	11200	11300	1.02	228000
	B	4	6500	4700	5600	1.16	113000	8000	5600	6800	1.18	137000
	C	6	5200	6000	5600	.93	113000	6800	7800	7300	.93	146000
Opp. jt.	D	8	8500	6500	7500	1.13	151000					
	E	10	7600	6800	7200	1.06	144000	7800	5600	6700	1.16	135000
	F	12	8200	7600	7900	1.04	159000	9200	10000	9600	.96	193000
	G	14	7600	7600	7600	1.00	153000	9500	10300	9900	.96	199000
2	H	17	10300	10100	10200	1.01	206000	11400	11000	11200	1.02	226000
	I	19	11000	9200	10100	1.09	204000	9700	7700	8700	1.11	175000
	J	21	4300	3700	4000	1.08	80000	5900	3500	4700	1.25	95000
Opp. jt.	K	23	9000	8000	8500	1.06	171000					
	L	25	11100	9900	10500	1.06	210000	10100	7100	8600	1.17	175000
	M	27	7500	7900	7700	.97	153000	7300	6700	7000	1.04	142000
	N	29	4700	2500	3600	1.31	73000	8500	6500	7500	1.13	151000
3	O	32	8500	7500	8000	1.06	159000	10200	9200	9700	1.05	195000
	P	35	6300	6100	6200	1.02	124000	8600	6000	7300	1.18	146000
	Q	37	4800	4600	4700	1.02	95000	6600	5600	6100	1.08	122000
Opp. jt.	R	39						7000	7000	7000	1.00	142000
	S	41	5900	7700	6800	.87	137000	13100	7700	10400	1.26	208000
	T	43	6600	6000	6300	1.05	128000	8700	6900	7800	1.12	155000
	U	45	7500	7900	7700	.97	153000	8100	5300	6700	1.21	135000
Average*			7500	7000	7300		145000	8900	7400	8200		165000
4	V	48	10600	8400	9500	1.12	190000	11400	11000	11200	1.02	225000
	W	50	10100	7700	8900	1.14	179000	10800	8000	9400	1.15	190000
	X	52	10200	7600	8900	1.15	177000	10800	7200	9000	1.20	182000
Opp. jt.	Y	55						8900	9700	9300	.96	186000
	Z	69	9400	8000	8700	1.08	175000	10300	9500	9900	1.04	199000
	a	71	9700	7700	8700	1.11	175000	7800	7400	7600	1.03	153000
	b	73	9400	8600	9000	1.04	182000	7000	7800	7400	.95	151000
Average*			9900	7900	8900		180000	9700	8500	9100		183000

*Values at points opposite a rail-joint are not included in the averages.

Table 28 for the 24 places on each rail opposite to one another at which the stresses were observed and also the corresponding stresses at 4 places opposite rail-joints of these stretches of track. The stresses at the outer edge and the inner edge of the base of rail given in Table 28 are plotted in Fig. 78 and 79 and the points are connected by fine full lines and fine dotted lines, respectively, and the mean stress in base of rail is also plotted and the points are connected by the heavy dotted lines. Although the stresses were measured at gage lines .25 in. above the bottom of the rail the values have been reduced to a position in the plane of the bottom of the rail by the method described in Article 38.

The values of the mean stress in base of rail from point to point along the track are fairly uniform except for a few places at which quite low stresses were found. Six values of the mean stress on locations 1, 2, and 3 (limestone ballast) ranged from 3600

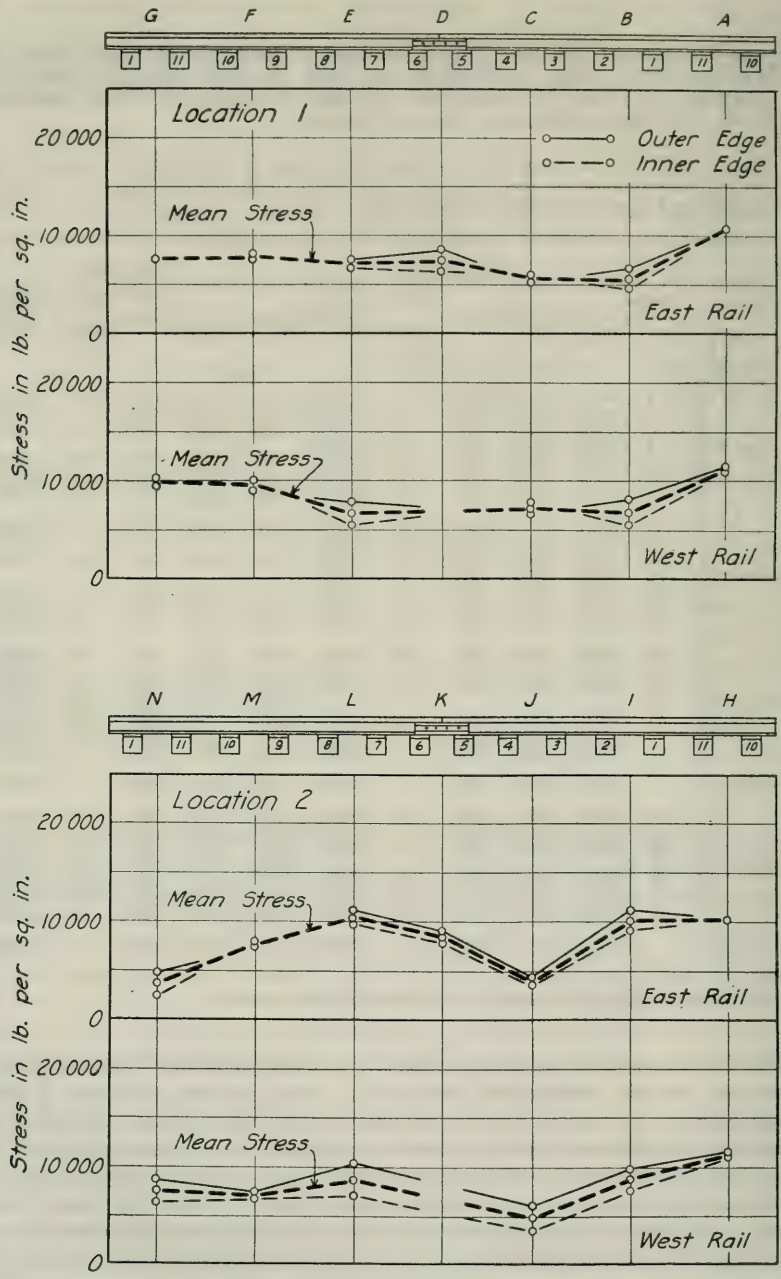
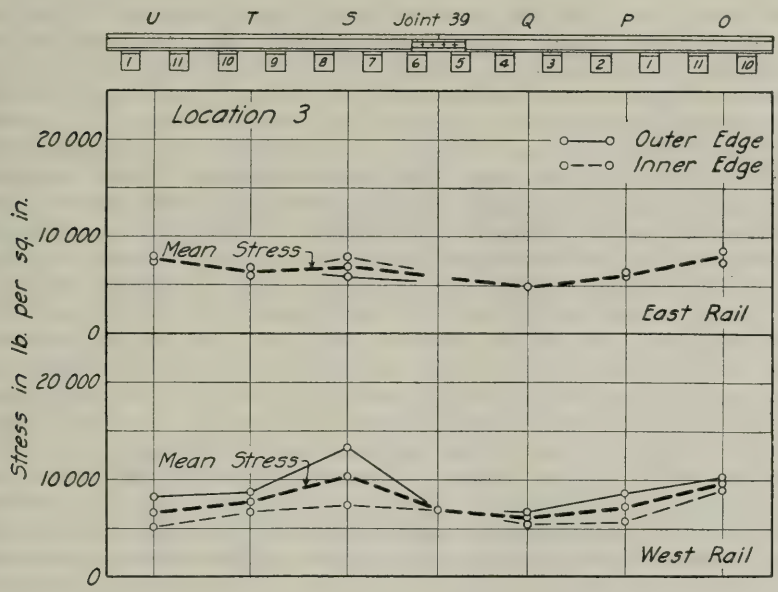


Fig. 78.—Stresses at Outer Edge and Inner Edge and Mean Stress in Base of Rail at the Rear Wheel when the Load Is Moved from Point to Point—Locations 1 and 2 (Limestone Ballast)—Tests on Missouri Pacific Railroad.



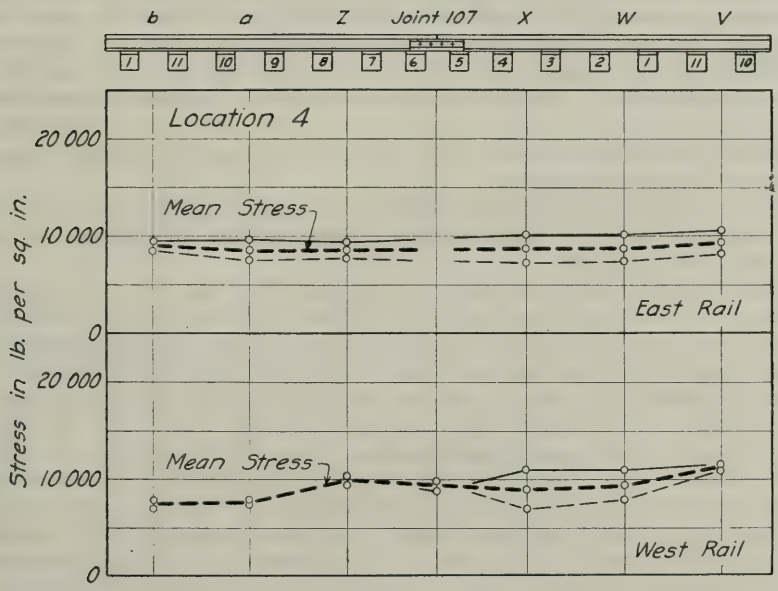


Fig. 79.—Stresses at Outer Edge and Inner Edge and Mean Stress in Base of Rail at the Rear Wheel when the Load Is Moved from Point to Point—Location 3 (Limestone Ballast) and Location 4 (Flint Ballast)—Tests on Missouri Pacific Railroad.

to 5600 lb. per sq. in. These low values were found at places where the two ties adjacent to the wheel had little play and little drop (probably .02 in. or less) and the rail and tie support was very stiff, and where for two or three ties beyond each way there was considerable play or drop (.06 in. or more), thus making a condition such that the two ties adjacent to the load take a proportion of the load much larger than the normal share, while the ties farther away take much less load than the normal share found with ties having uniform supporting values. These conditions combined to make the stresses and bending moment in the rail under the load at these points much less than would be developed with uniform tie support. For locations 1, 2 and 3 the average of the mean stresses in base of rail (not including the stresses in rail opposite a rail-joint) is 7300 lb. per sq. in. for the east rail and 8200 lb. per sq. in. for the west rail. Omitting the six low values referred to above, the average of the mean stresses for locations 1, 2 and 3 are 8200 lb. per sq. in. for the east rail and 8400 lb. per sq. in. for the west rail, making an average value of the mean stress for both rails 8300 lb. per sq. in. This average stress is smaller than the analytical value 9200 lb. per sq. in. calculated with the average value of u (5100) found for the observed net depressions at the east rail. For location 4 (flint ballast) the average of the mean stresses in the east rail is 8900 lb. per sq. in. and for the west rail 9100 lb. per sq. in.—making an average for both rails of 9000 lb. per sq. in. This average value is smaller than the analytical value of 10,300 lb. per sq. in. obtained by the use of u of 2900 determined from the observed net depressions at the east rail. It may be added that, except for the six low values heretofore referred to, the mean stresses in base of rail at most of the places in locations 1, 2 and 3 do not vary greatly from the average mean stress. For the remaining 30 places at which measurements were made, five places gave values 36, 35, 29, 26 and 25 per cent greater than the average mean stress (8300 lb. per sq. in.) and two 26 and 25 per cent less than the average. For the other 23 places the average variation from the average value of the mean stress was 13 per cent. The mean stresses in location 4 are still closer to their average. Altogether, the uniformity of mean stress from point to point may be considered to be much better than exists in most track. It is evident that the uniformity is influenced by such things as uniformity of rail bearing from tie to tie by reason of lesser variations in play between rail and tie bed, uniformity of bearing of rail on tie-plate and tie, and lack of great variation in stiffness of tie support.

It may further be noted that the average of the mean stresses in base of rail for points opposite a rail-joint is almost the same as the average value of the mean stress at places away from a rail-joint.

In the 52 places measured at location 1, 2, 3, and 4, the stress at the outer edge or inner edge of base of rail differs from the mean of the two stresses by an average of 7 per cent of the mean stress. Of the 52 values, four give an edge stress of more than 20 per cent greater or less than the mean stress, with ratios of 1.31, 1.25, 1.26, and 1.21. Generally the greater stress is in the outer edge, and there are few reversals from point to point. The variations of the edge stress from mean stress may be said to be very small, much less than is to be found in track generally. It should be noted that the lateral bending observed in these tests is principally that due to the condition of the track and not that due to the condition or motion of the rolling stock. The lack of lateral bending stresses may properly be attributed mostly to the uniform bearing of rail on tie-plate and tie-plate on tie and to insuring that the adzed surfaces at the two ends of the tie lie in the same plane obtained by reason of methods used in adzing and boring for the tie-plates and tie. The fact that the ratio of stresses at outer edge to mean stress in base of rail is greater than unity and thus that there is generally an outward bending of the rail may be attributed in large part to the cant of the rail being only 1 in 40;

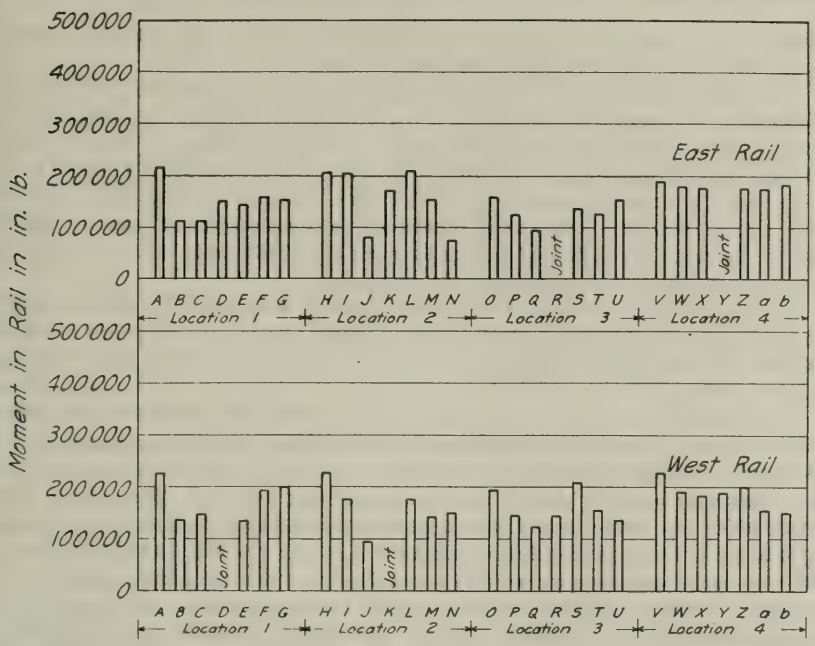


Fig. 80.—Vertical Bending Moment in North Rail and South Rail at the Rear Wheel when the Load Is Moved from Point to Point—Locations 1, 2, 3 and 4—Tests on Missouri Pacific Railroad.

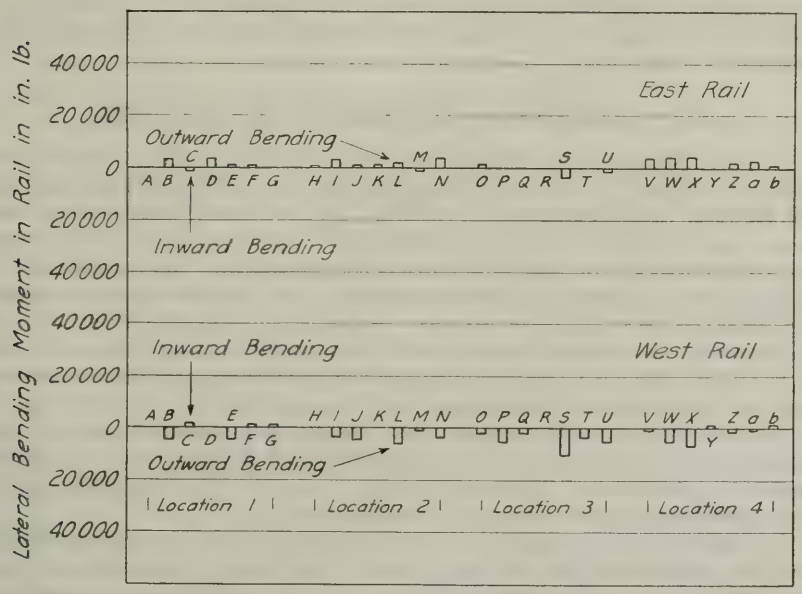


Fig. 81.—Lateral Bending Moment in North Rail and South Rail at the Rear Wheel when the Load Is Moved from Point to Point—Tests on Missouri Pacific Railroad.

rails with small cant or no cant have been found most often to give outward bending of the rail and those with large cant to give inward bending.

The values of the vertical bending moments in the rail from point to point, calculated from the mean stress in base of rail, are also given in Table 28. Here, as in the case of stresses, the average bending moment for locations 1, 2, and 3 (155,000 in-lb.) is less than the analytical moment (185,000 in.-lb.) and that for location 4 (181,000 in.-lb.) is less than the analytical moment (208,000 in.-lb.), although if the points having very small stresses had been omitted in calculating the averages the difference would be smaller. It seems probable that if measurements had been made between all ties the two values would have been more nearly comparable.

In Fig. 80 the magnitudes of the vertical bending moments are plotted to scale in the order of the place in track for the four locations. Except for the points developing relatively low moments the variations along the track may be called small variations from the average.

The magnitude of the lateral bending moment in the rail, calculated from the excess or deficiency of stress at the outer or inner edge of base of rail as compared with the mean stress, is plotted for the east rail and the west rail in Fig. 81 for the four test locations, inward or outward bending from the track being indicated. The scale is similar to that of Fig. 73. Here again it should be kept in mind that the lateral section modulus of a rail is less than one fifth of the vertical section modulus (.194 for the 110-lb. R.E. rail), and hence that for a given lateral bending stress the corresponding bending moment is relatively smaller than the vertical bending moment. The largest lateral bending moments are 10,000 and 7000 in.-lb.—the others are smaller than 6000 in.-lb. and all average 2600 in.-lb. It is evident that the lateral bending in this track due to static load is extremely small, owing, as has been said, to the excellence and uniformity of the bearing of rail on tie-plate and tie-plate on tie. With reference to the direction of the lateral bending, it may be noted that for both rails the bending was in nearly all cases outwardly of the track and only at one inward bending was there a value greater than 2000 in.-lb.

VII. DISCUSSION OF TESTS OF RAIL-JOINTS

47. **The Function and the Action of the Rail-Joint.**—In the Fifth Progress Report, the action of the rail-joint as a whole and that of the individual joint bars were described and discussed on the basis of the experimental data and its interpretation in the light of analytical considerations. In Chapter VI of that report and in the Review at the end of the chapter, the function of the rail-joint and its principal modes of action were treated quite fully. The additional experimental data and information from track and laboratory tests given in this Sixth Progress Report have confirmed the principal findings of the last report and have given new facts and principles applicable to a fuller comprehension of the modes of action of the rail-joint. In considering the information it will be found necessary to repeat some of the statements made in the preceding report. Besides, in a subject on which so little analytical and experimental discussion is available some repetition may be desirable, especially as repetitions of statements and ideas and views will doubtless aid in getting a better comprehension of the way a rail-joint acts.

In moment-taking properties an ideal rail-joint and the supporting substructure should furnish the same stiffness of track as does the continuous rail at points away from the rail-joint. This condition is not fully attainable. An approach to it may be obtained by combining a rail-joint that is somewhat less stiff than the

rail with a somewhat greater stiffness of the rail support at the rail-joint than elsewhere in such a way that the rail depression will differ only slightly as the wheel rolls along and the evenness and regularity of the rail surface under load will not change much along the track upon the application of traffic. At any rate an optimum of stiffness of rail-joint and a somewhat fuller or stiffer tie support of the rail at and near the rail-joint may be expected to be favorable to the rail-joint. The term moment-taking properties of course does not provide for adequacy of resistance of the rail head to flow, because of the discontinuity at the rail ends, nor does it consider opportunity for longitudinal movement at rail ends with changes in temperature—these and other features must have separate consideration.

In a discussion of the rail-joint the following principles and remarks may be useful in connection with the consideration of the action of joint bars of different forms and the way in which they function:

(1) The joint bars of the usual forms of rail-joints act largely or principally as simple beams with the load they carry applied by the rail head on the upper fishing surface of the joint bars close to the ends of the two rails and with their points of support (reactions) distributed at different places along the base of rail when positive moment (downward bending) is applied (see Fig. 1).

(2) For positive moment the resultants of the bearing pressures of the rail head on the upper fishing surface of the joint bar may be considered to be applied in the neighborhood of the rail ends (the resultant of the pressure being close to the rail end) and on each half of a joint bar two resultants of the bearing pressure of the lower fishing surface of the joint bar on the base of rail (upper surface of flange) will be located, one at 4 in. from the rail end or somewhat more or less and the other farther along toward the end of the joint bar, the positions depending upon bearing fit and other conditions. For worn bars the top resultant will be further from the rail end and the longitudinal distance from this resultant to the interior reaction will generally be smaller than for well fitting bars.

(3) Because of the difference in the flexural curves of the rail and the joint bar under vertical bending moment there is little vertical restraint to modify the conditions of simple beam action, but the lateral restraint given to the joint bar at various positions along its length influences its lateral action and modifies the position of the neutral axis developed at the various sections along the joint bar.

(4) Stiffness of the rail-joint as a whole (resistance to deflection as compared with that of the full rail) is an essential property of a good rail-joint. Besides the need of excellence of fit and absence of play between joint bar and rail, the size and shape of the bar section should be such as to give it the maximum obtainable deflection-resisting properties (stiffness of beam action).

(5) In addition to forcing the joint bar into a place close against the fishing surfaces of the rail and producing lateral restraint in the joint bar and preventing the joint bar from working out of place under bending and twisting action, bolt tension has been found to develop elastic springing action in the joint bar which may be a principal source of the maintenance of bolt tension in rail-joints subjected as they are to repeated movements and wear in track. The value of this springing action and the useful limitations in the magnitude of the bolt tension will be dependent upon the shape and design of the joint bar and the opportunities for useful lateral springing deflection.

(6) The moment developed in a rail-joint in track for given wheel loads is dependent upon the amount and distribution of the tie reactions against the rail developed at and near the rail-joint, as well as upon stiffness of rail-joint and the amount of play and quality of fit between rail-joint and rail. It is evident that relative spacing of ties at and away from the rail-joint and also the relative vigor or effectiveness of tamping joint ties and likewise the differences in the play between rail and rail support from tie to tie all influence the magnitude of the bending moment developed in a rail-joint. The moment developed in the joint bars is almost always less than that in the full rail.

(7) The design of the form of the joint bar (section, longitudinal form, and other properties) is worthy of still further study.

In the articles in this chapter, discussion is given on some of these points, questions are raised in other directions, and comparisons of tests are given.

48. **The Action of Several Forms of Joint Bars.**—A comparison of the mode of action of several forms of bars in rail-joints and of the differences in magnitude and distribution of stresses over their mid-section and of other characteristics, as determined generally in laboratory tests described in Chapter II "Laboratory Tests of Rail-Joints", will be useful in understanding something of the similarities and differences in their action upon the application of load.

The new and unused N.Y.C. and Penn. angle bars for heavy rail (38 and 38½ in. bars for 127-lb. and 130-lb. rail, respectively), described in Articles 7a and 7b, showed excellent fit in the rail-joint throughout. In both joints, the compressive stress at the top of the bar developed at mid-section under load (see Fig. 6 and 8) was double the tensile stress at the gage line near the bottom of the bar, even though the distance from the upper and the lower gage lines to the horizontal geometrical axis was nearly the same. This difference in stress is due to the dissymmetry of the bar section. Longitudinally of the bars the stress at the top decreases rapidly away from the mid-section, while at the bottom it remains nearly constant throughout the middle 8 in. of length of the bar and for a greater distance when the bolt tension is low. These differences may be explained by the changes in lateral restraint of the bar from point to point along the length and their effect in modifying the inclination of the neutral axis of the unsymmetrical section. The angle of inclination of the neutral axis from horizontal at mid-section of the N.Y.C. angle bar was +15° with 20,000 lb. bolt tension and +20° with 2000 lb. bolt tension; at sections 4 in. on either side of mid-section the corresponding angles of inclination were —15° and 0. With the Penn. angle bars the inclination at mid-section was +25° and +25° and at sections 4 in. on either side —45° and 0 for the bolt tensions of 20,000 and 2000 lb., respectively. In both N.Y.C. and Penn. rail-joints, the longitudinal distribution of compressive stresses and bending moments show a peaked form in the middle 8 in. which is less marked at a bolt tension of 2000 lb. than at 20,000 lb. On the application of load the bar at mid-length twisted somewhat, moving slightly outward at the top and inward to a greater degree at the bottom, resulting in a noticeable decrease in the tension of the inner bolts—due mainly to lack of symmetry in the section. The lower bolt tension gave more twisting and bottom lateral movement than the higher tension. The distribution of the stresses over the section from top to bottom at mid-length was similar to that found in bars of similar section given in the Fifth Progress Report.

The rail-joint herein termed the Santa Fe Symmetrical Type Rail-Joint for 130-lb. rail has joint bars closely resembling in section the near-symmetrical study

section F designed for discussion in the Fifth Progress Report (see Fig. 120 of that report). Except for having a length of 26 in. and 4 bolts instead of 39 in. and 6 bolts the joint bars were the same as those in the track tested on the Chesapeake and Ohio Railway. The tests showed that the fit between the rail and the bars of the joint tested in the laboratory was not entirely good, especially in one of the halves of their length. With these near-symmetrical bars and the rail-joint under a uniform moment of 400,000 in.-lb. the stresses and moments developed at the mid-section (see Fig. 13) were found to be the same for bolt tensions of 20,000 and 2000 lb., regardless of possible differences in restraint given by the two bolt tensions in the two tests. It was also found that for both bolt tensions the stresses at top and bottom gage lines had approximately the same magnitude at corresponding points along the length of the bars. This lack of difference in stress at the top and the bottom is attributable to the symmetry of the section and is in marked contrast to the variability found in rail-joints of the angle bar type as shown in the N.Y.C. and Penn. angle bars just discussed. Besides, the stresses, except at areas affected by strong concentration of bearing pressures, correspond closely to the stresses calculated from the applied moment by the ordinary formula of mechanics based on a horizontal neutral axis. A similar correspondence in stresses was observed in the tests of joints of symmetrical section on the Chesapeake and Ohio Railway. It is evident that this form of section acts effectively throughout in the manner of the beam action generally assumed in treatises on resistance of materials except as certain points in the section may be affected by the bearing pressures applied by the rail, all of which is in contrast with the deficiency in stress developed in the flanges of the angle bar form of section.

The lack of good fit in the bars of the joint tested in the laboratory was the source of vertical movement between bar and rail, which contributed to the deflection of the joint. For a bolt tension of 20,000 lb., upon applying load there was a very slight lateral movement outward at the top of the bar at mid-length and a slight inward movement at the bottom (see Fig. 14). At other places, the top of the bar was stationary or moved slightly outward; at the bottom the movement was slightly inward along the whole length. For a bolt tension of 2000 lb. both top and bottom of the bar remained close to the initial position throughout the middle 12 in. At the ends there was outward movement at both top and bottom. The higher bolt tension was accompanied by a somewhat smaller vertical movement between rail head and bar, averaging less than .002 in. closure at the rail ends on application of load and about .002 in. opening at the bar ends for the higher bolt tension, while for the low bolt tension the corresponding values averaged .007 in. closure at rail ends and .008 in. opening at bar ends. The higher bolt tension thus will reduce the amount of movement between rail and joint—the decrease depending upon the fit of the joint.

The pair of the Penn. symmetrical type joint bars for 130-lb. rail (length 38½ in.), taken from a joint in the track at Claymont, Delaware, tested in the laboratory showed results similar to the Santa Fe joint bars (see Fig. 12). The stresses at the top and the bottom of the bars are nearly proportional to the distance from the horizontal gravity axis and agree fairly closely with the calculated stress. The stresses with bolt tensions of 20,000 and 4000 lb. are strikingly similar. The distribution of stresses and moments along the length of the bar are almost identical for the two bolt tensions. The conditions of fit and restraint of the bars are not particularly affected by change in bolt tension. The design of this bar is stocky, with a very thick web. Its section modulus is only 70 per cent of that of the Penn. L-3 angle

bar, and necessarily the stress developed is higher, though not correspondingly so. The results of the tests, however, bring out some of the advantages in the symmetrical form. Only a few bars of this design have been used by the Pennsylvania Railroad.

The striking feature of the tests of the Continuous rail-joint was that in both head-bearing and head-free bars the reflexed flange under the rail did not act entirely integrally with the rest of the section and thus the greater part of this flange was not effective in resisting bending moment in the way that is assumed ordinarily in the mechanics of beam action, and therefore that the maximum stresses are greater than would be expected. At the bottom face of the reflexed flange (see Fig. 16) the stress at the outer edge averaged 20,000 lb. per sq. in. and at the inner edge 10,000 lb. per sq. in. for the head-bearing bars, 22,000 and 10,000 lb. per sq. in. at the corresponding points for the head-free bars, as compared with the analytical value of 19,000 lb. per sq. in. for both points. The stress at the inner edge of the reflexed flange is thus nearly 50 per cent less than the analytical stress at this gage line for the two forms of Continuous joint bars. The center deflections on three longitudinal lines or elements of the length of the head-free Continuous bars located at the top of the bar, at the outer edge of the bottom of the reflexed flange, and at the inner edge of the reflexed flange differed from one another considerably. On the stress diagram at mid-section, no single axis at any inclination could be found for which the observed stresses were proportional to the distances between gage point and axis. The stresses at the top were greater than the analytical stresses based on a horizontal axis. The observed stress at the top of the bar at mid-section for the high and low bolt tensions in the head-bearing bars is about 28 to 40 per cent greater than the analytical stress of 21,000 lb. per sq. in. based on a horizontal axis and in the head-free bars about 10 to 25 per cent higher, though in the latter case it is apparent that because of the position of the rail bearing pressure on the bar the gage line used at the top of the bar does not give the actual maximum stress, which is probably nearer the fillet of the rail. Regardless of this, the maximum stress is less than has been found with other forms of bars, owing of course to the heavy section. The distribution of the stresses at the top of the bars along their length is similar to that of the bars heretofore discussed, except that the stress diagram for the head-free bars is less peaked (more blunted) at the middle of the length than for the head-bearing bars, due both to an outward movement of the top of the bar at mid-length and to the distribution of the bearing load a greater distance back from the rail end—both of which result from the bearing being at the rail fillet. In both forms of bar, the stress at top gage line 4 in. from mid-section is 40 or 50 per cent of that at mid-section.

As just stated, the observed stress at a top gage line at mid-section was less in the head-free Continuous bar than in the head-bearing bar. As the upper bearing of the rail is at the fillet it seems probable that the gage line used on the head-free bar does not give the maximum stress, which may be closer to the bearing area. The bluntness of the stress distribution diagram at and near mid-section is an indication that the load bearing or contact area extends well back from the rail end and that its centroid is farther from the rail end than is usual with the head-bearing bar. The greater slope of a bearing area on the fillet of the rail permits such a variation; the rounding form of the bearing contact may also facilitate a better fit at the two rail ends and possibly also may obviate to some extent the "digging in" of the rail ends at the end to the load bearing contact areas. Upon application of load the vertical movement of the head-free bar with respect to rail at mid-length

is greater than with the head-bearing bar, and the magnitude of this movement is greater as the bolt tension becomes less. This movement and the rather marked increase in tension in the inner bolts upon application of load indicates the desirability of maintaining fairly high bolt tension in the head-free Continuous joint. Even in the head-bearing Continuous joint, high bolt tension is important.

The form of the Continuous bar gives opportunity for adding metal below the rail base and likewise the depth of the bar can be increased and a heavy section obtained. As the reflexed flange does not act fully with the rest of the section in resisting flexure, some ineffectiveness of the added metal must be accepted. However, the form permits the design of a heavy and strong joint bar. With both the head-bearing and the head-free Continuous bar it is essential that the fit between bar and rail be excellent.

In the Muller rail-joint tested, a bearing contact was provided for positive moment on the top of the joint bar for a length of 3 or 4 in. each way from the rail ends and a bearing contact on the base of the rails for about 3 in. from the ends of the bar, and the bearings are limited to these locations. A characteristic of the rail-joint tested is that in assembling the joint a considerable tension must be put into the end bolts to bring the ends of the bars to a bearing on the base of the rail at the ends of the bars for supporting the reactions in acting as a beam, and the lateral bending moment thereby put into the bars develops high initial bending stresses in fibers of the bars at and near mid-section. For the rail-joint tested the initial stresses due to the lateral bending thus developed were found to be 30,000 lb. per sq. in. at the top gage line and 75,000 lb. per sq. in. at the bottom gage line (extreme outside edge of the bottom flange of the bar) on the assumption that the elastic limit of the metal is not exceeded. In the test with a load of 25,000 lb. (vertical moment of 300,000 in.-lb., 75 per cent of that applied to the other rail-joints tested), the stresses at the top gage line due to the applied load were 30,000 and 40,000 lb. per sq. in. compression in the two bars, respectively, and the stresses at the bottom gage line 2,000 and 10,000 lb. per sq. in. tension. It is apparent that the resulting stresses caused by tightening the bolts in setting up the joint and in applying the load of 25,000 lb. averaged 2000 lb. per sq. in. compression at the top gage line and 80,000 lb. per sq. in. at the bottom gage line. Thus the initial stresses put into the bar by tightening the bolts greatly changed the actual stresses present under an applied load. The magnitude of the initial stresses depend, of course, upon the longitudinal form of the joint bar. It is evident that under ordinary track conditions the rail-joint tested would not have opportunity to resist negative moment, for the middle of the span rose .15 in. before developing negative resistance. It may be said then that this rail-joint developed very high initial stresses and that the resulting stresses under load were extremely high, that the large deflections indicate that it is lacking in desirable stiffness, and that it is ineffective in resistance to negative moment.

49. **The Position and Magnitude of the Bearing Loads and Reaction Forces Acting upon the Joint Bars.**—In a number of tests of rail-joints both in laboratory and in track the moments at the various sections along the length of the joint bars were calculated from the observed stresses and plotted to give moment distribution diagrams. For these diagrams bearing loads and reaction forces representing the resultants of the actual forces and similar to those denoted by Q and R' and R'' in Fig. 1, were computed which would produce a distribution of moment along the length of the bar approximating that of the real moment distribution curve. Generally four reaction

forces along the length of the bar were assumed in the attempt to fit the moment curve —sometimes only two or three were needed. It should be understood that the position and magnitude of these forces are only approximately correct. Other similar sets of forces might be chosen; the position of a force may be taken an inch or possibly more away from that given, resulting in some changes in the magnitude of the forces required to produce the moments found at the various sections along the bar. The calculated values of the bearing loads and reaction forces at the top and bottom fishing surfaces of the bar found by the method used furnish information that will be helpful in judging of the position and magnitude of the loads and reactions acting upon the joint bars with the wheel over the middle of the joint.

Fig. 82 gives calculated bearing loads and reactions for the laboratory tests for which distribution of moments was obtained. The magnitude reported is the value for two bars of a joint. From the shape of the original moment distribution diagrams (peaked at the middle), it is considered that the two bearing loads (resultants) are applied on the top of the bar quite close to the rail ends, except that in Penn. L-3 (lat. def.) the resultants were found to be 2 in. back from the rail ends and in I.C. joint one resultant was 2 in. back from its rail end. The magnitude of the bearing load applied by the two companion rails generally differed, though it may be seen that in three cases the resultants found are equal. The values of the bearing loads applied by each rail in developing the moment of 400,000 in.-lb. at mid-section of two bars (the moment applied to the I.C. joint was only 240,000 in.-lb.) range from 30,000 to 80,000 lb. on the two bars, which of course are not equally divided between the two bars. Generally there are two reactions acting on each half of the bars, the main one at about 4 in. from the rail end and a second one well out toward the end of the bar. In one joint (Penn. L-3 angle bar No. 1 (lat. def.)), by the deforming process the bottom flange instead of being relieved of contact bearing throughout the quarter region has taken a form that gives a third reaction contact, and in the deforming of the top flange the load bearing contact has been moved away from the end of the rail. For the 38-in. bars the magnitude of the interior reaction generally ranged from 13,000 to 62,000 lb. for two bars and the end reaction from 9,000 to 18,000 lb. For the Santa Fe 26-in. bars the interior reactions range from 9,000 to 39,000 lb. and the end reactions from 26,000 to 34,000 lb. For the I.C. 24-in. bars the distribution is unlike the other joints—the fit is irregular. All the values given are the sum of the pressures on two bars—the division between them in all probability is uneven and likewise the position of the resultants is not the same on the two bars.

Several significant conclusions are brought out from such tests. The position of the bearing load applied by the rail to the bar when the load is at the middle of the joint is necessarily very close to the end of the rail in well fitting bars of the ordinary forms. The form of the flexure curve of the rail for a few inches back of its end and the form of the flexure curve of the joint bar throughout the same location are such that an interior reaction bearing contact is produced along an area not far away from the rail end with its centroid approximately 4 in. from the rail end, as shown in these diagrams. The closeness of this reaction force to the load bearing force, in horizontal distance between the two vertical forces, is productive of a large increase in moment developed in the short length of 4 in. or so. This sudden increase in moment is indicated by a peaked form in the moment diagram. As a consequence high values of both the top bearing pressure and the interior reaction are developed—values which are much higher than would be found if the load bearing pressure and the main reaction were further apart. The closeness of the load bearing contact to the end of the rail, together with

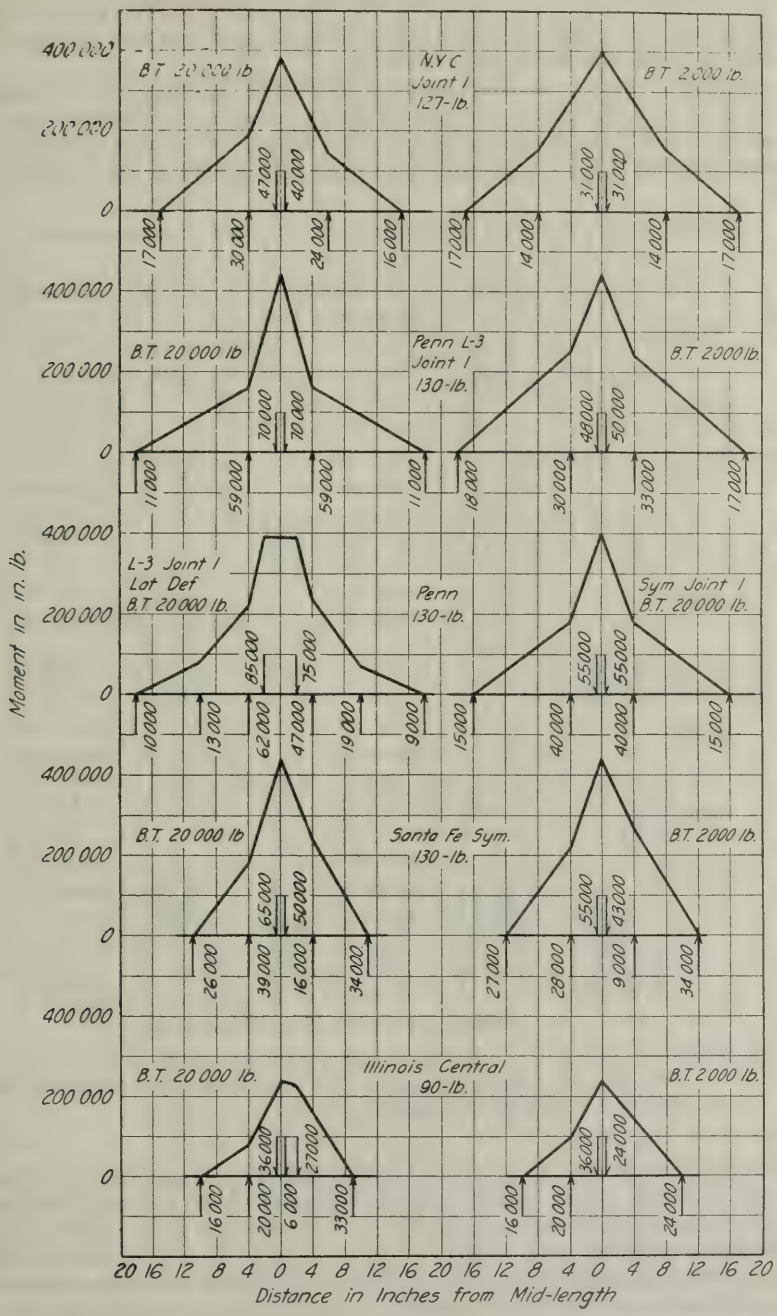


Fig. 82.—Position and Values of Bearing Loads and Reactions That Would Develop the Moments Observed at Sections along the Joint Bars in Laboratory Tests.

the lack of curvature in the rail at its end and with the maximum curvature of the bar coming at the same place, results in a greater detrusion at this place, a "digging in" by the rail end as the statement is sometimes made.

Similarly in Fig. 83 are given moment distribution diagrams and corresponding bearing loads and reactions on two bars for the 39-in. Santa Fe symmetrical type bars tested in the track of the Chesapeake and Ohio Railway at Ashland, Kentucky. The observed moments in the bars at mid-section range from 120,000 to 250,000 in.-lb., val-

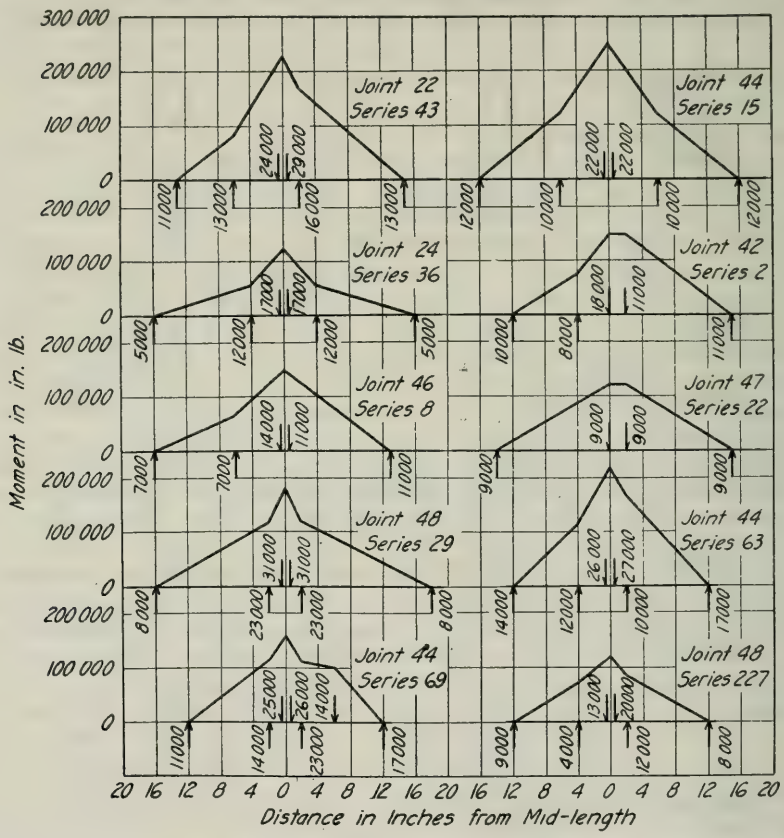


Fig. 83.—Position and Values of Bearing Loads and Reactions That Would Develop the Moments Observed at Sections along the Joint Bars in Track of the Chesapeake and Ohio Railway.

ues which are smaller than the moment of 400,000 in-lb. that was applied in the laboratory and also more variable because of the variability of the tie reactions in the track. There was also variation in bolt tension and in fit of bars and in their position, which contributed to variations in magnitude and position of the loads and reactions acting on the bars. The moment diagrams indicate that the bearing load was applied to the top of the bar close to the rail end, except that in two cases the resultant for one rail was 2 in. from a rail end. In most cases there were two reactions for each half of a bar.

When there was only one reaction and the bolt tension was observed, the bolts had low tension or were loose. With two reactions in each half length the distance from mid-section of bar to position of an interior reaction ranged from 2 to 6 in. The magnitude of the interior reactions was moderate; it ranged for joints with tight bolts from 12,000 to 23,000 lb. at one rail end for two bars, and with low tension from 8,000 to 12,000 lb. or was absent. The end reactions came at 12 in. away from mid-section for five joints and at 14 and 16 in. for five joints; of the latter two had low bolt tension and two tight bolts. Except in the case of low bolt tension, the end reactions were smaller than the intermediate reaction; the range was from 5,000 to 17,000 lb. for two bars.

It is evident that if bars were formed along their length in such a way that there will be relief from reaction bearing contacts for positive moment at places other than towards the end of the bar (absence of reaction at R' in diagram (b) of Fig. 1 leaving only R'', or R as in diagram (a)), the magnitude of the top bearing force (Q in Fig. 1) will be decreased.

It was also found in the tests that in joints with bars having close fit all along their length, when the wheel load is directly over a section in the region of the quarter points of the length of the bar the curvature of the rail at that point may cause contact on the bar at a nearby point and the moment developed there may be somewhat greater than it is at the same section when the load is directly over mid-section. (See Fig. 23 and 24.) For bars having relief of contact with rail at quarter points of the length, the moment at a given section will increase gradually to a maximum with load over mid-section.

50. **Bolt Tension, Its Function and Action, and the Elastic Lateral Springing of Joint Bars.**—As given in the Fifth Progress Report the purpose of providing tension in bolts may be stated to be as follows: (1) To draw the bar as far into its place between the two fishing surfaces of the rail as the roughness of surface and differences of dimensions of the two rails and the two bars will permit. (2) To prevent the bar working out of place when the bending and twisting of bars and rail may act to force it out. (3) To make the bar fit more closely to the rail and thus to decrease the vertical movement between bar and rail produced upon application and release of load. (4) To give lateral restraint to the angle bar type of joint bar and thus to reduce as far as practicable the deflection of the neutral axis from horizontal and the corresponding lateral bending of the angle bar or other unsymmetrical type of section and also to reduce the twist that accompanies this form of section when a vertical load is applied to the joint. (5) In the case of lateral bending to act as an important part of the moment resisting procedure of the joint, both in the case of small bolt tension and in the case of bolt tension sufficiently high to bring into play integral action in the joint resistance.

It will be remembered too in connection with purpose No. 1 that after a bar has been put in place and the bolts tightened, repeated application and release of load (especially with the development of both positive and negative moment) will result in decreasing the bolt tension as the bar is worked or drawn into closer relation or more nearly complete contact with the rail fishing surfaces, every car adding continued application and release of load. It is apparent that any working into place closer to the rail will act to decrease the magnitude of the bolt tension except as it may be modified by initial bending and springing of the bars or other device for reducing the tension loss. In newly placed joints, one or more re-tightenings after

the joint bars have been worked in under the action of traffic loads will cause the joint to assume a more nearly stable bolt tension.

The working out of place, referred to in purpose No. 2, is more apparent with the angle bar form of joint bars than with bars of the symmetrical type, though the twisting action found when rail and tie-plate bearings are uneven and irregular may contribute somewhat to decrease in bolt tension in any form of rail-joint. It should be noted that tension in the inner bolts tends to pull the bottom of the bar inward toward the rail at mid-length of the bar when under positive bending moment and that the resulting difference in the curvature of the bar and the rail developed near the rail ends frees contact between the lower fishing surfaces of bar and rail at and near mid-length, and also that a corresponding tightening occurs in the end bolts as the upper fishing surfaces are freed near the bar ends, while opposite effects are developed with negative bending moment. The lateral restraint referred to in purpose No. 4 is particularly important with the angle bar or other unsymmetrical form of joint bar, and high bolt tensions are advantageous in producing lateral restraint and reducing longitudinal stresses and in making the bar act more efficiently. It was stated in the Fifth Progress Report that the bolt tension needed for purpose No. 5 in the case of straight track and light curves is within the limits of the bolt tension desired for other purposes.

As referred to in the last paragraph, momentary decrease in bolt tension is found when the top fishing surface of the bar near the middle of the length remains in place against the under side of the head of rail and the lower fishing surface is freed from contact, as occurs when a positive moment is applied, especially with the angle bar form. Similar conditions are found at the ends of the bar. Twisting movement of the rail-joint may give similar changes in tension. These changes are largely elastic, but repeated applications of load will give conditions that tend toward permanent reductions in tension.

Wear of bar and rail at fishing surfaces is productive of loss in bolt tension, particularly in the inner bolts. Tightening the inner bolts, however, does not usually bring back the full contact at the top bearing near the rail ends, for except with untreated bars little wear is to be expected above these bolts, and with wear at the top fishing surface near the ends of the rail play between rail ends and bar will remain and hence greater deflection of the joint as a whole—an undesirable condition. With bars having requisite excellence of fit, made of suitably thermally treated steel, and having properly maintained bolt tension, together with adequate and uniform rail support, the wear should not be a troublesome factor.

As stated in the Fifth Progress Report, four bolts in a rail-joint may be said to be sufficient. In the angle bar the end bolt is of most service when positive moment is applied and the inner bolt for negative moment, and in the symmetrical bar both bolts will be useful for both conditions, and in both forms the inner bolt and the end bolt are effective in developing resistance to lateral bending. However, it is evident that advantages accrue with the use of six bolts. A loose end bolt or a loose intermediate bolt or a loose inner bolt will have its function taken at least partly by an adjoining bolt. Either the end bolt or the intermediate or inner bolt will give desirable restraint for resisting vertical bending moment, and all bolts that have a fair amount of tension will be useful in resisting lateral bending in the joint. The number of bolts need not be fixed by the length of the joint bars or by the question of supported versus suspended joints, for six bolts have been used very satis-

factorily with bars 27 in. long (commonly thought of as a short bar) in suspended joints and would apply to a supported joint. The cost of the two additional bolts and of their maintenance will need consideration in weighing the advantages.

Article 10 "The Lateral Springing of the Joint Bars Due to the Application of Bolt Tension and Vertical Loads" gives pertinent information on the part played by the bending of the joint bars for 130-lb. rail in maintaining bolt tension when "working in" or wear tends to decrease the tension. In this connection it will be well to bear in mind that the elastic stretch in a 1-in. bolt of the length ordinarily used in rail-joints is only about .005 in. for a bolt tension of 20,000 lb. Extremely slight movements of the two bars toward each other would, of course, cause a loss in this stretch and therefore a loss in the tension, since with the ordinary pitch and no distortion of the bolt thread and nut thread a movement of .005 in. would correspond to only one twenty-fifth of a turn of the nut. However, the spring of the bar by its bending under application of bolt tension is such that a movement of the two bars considerably greater than .005 in. will not cause full loss in tension or any large part of it. For the data reported in Article 10 the movement of a nut in tightening from 5000 lb. to 20,000 lb. is 10 to 20 times the corresponding stretch of the bolt (or more). In unwrenching, the same change in tension was accompanied by a much smaller movement of the nut, so that the effectiveness of the flexure of the bar is less than that in wrenching, but the tests show that flexure in the bar is an important factor in maintaining bolt tension. As in the case of many spring washers, the travel of the spring through the lower range of tension is large and that in the higher range is smaller. Since the important part of the range may be said to be between, say, 5000 and 20,000 lb., the characteristics through that range should be noted in judging of the effectiveness of the bars in maintaining bolt tension. It is evident from the data and from the smallness of the stretch of a bolt that tensions beyond 20,000 lb. are relatively ineffective in holding joint bars in place, since a relatively small movement of the bar causes a loss of considerable tension. It follows that the wrenching of bolts to a tension of 40,000 or 50,000 lb., as is sometimes practiced, gives little useful result in maintaining bolt tension, and it may be productive of ill effects in other ways such as excessive resistance to temperature movements.

The desirable magnitude of the bolt tension then may be said to be limited, in one way, by the limit in effectiveness of the lateral flexural action of the bars in maintaining tension under changes in lateral position of the bars by wear or otherwise, or by the effective range given by any auxiliary device used for the same purpose. For the joint bars tested this upper limit may be called 20,000 lb. A lower limit may be set by the least magnitude which will hold the bars in proper position to function properly. A further advantage in the higher tensions lies in reducing the play and deflection of the joint; this will be considered in the next article. It is evident from analysis and tests that the unsymmetrical bar needs a higher bolt tension than the symmetrical bar. The dissymmetry of the ordinary angle bar form is helped in efficiency and in reduction in deflection by the higher bolt tensions, and with the higher bolt tension there is less swinging inward of the bottom of the bar at mid-length. The principal disadvantage of a very low bolt tension for the symmetrical type of bar is the resulting greater deflection in the whole rail-joint and probably a greater wear.

The tests herein reported confirm the finding given in the Fifth Progress Report that for the symmetrical type of bar a minimum bolt tension of 5000 lb. may be expected to give satisfactory conditions for both vertical bending and lateral bending on straight track and light curves. The corresponding minimum tension desirable for the angle bar may be given as 10,000 lb. The upper limit of useful tension for the ordinary forms of rail-joint may be thought of as 20,000 lb. These values apply to track conditions after the bars have been worked into place and approach a fairly stable position. It should not be forgotten, of course, that the higher bolt tensions increase the resistance to movement of the rail in the joint with changes in temperature, but the movement will take place in the joint and in the rail end that has the least resistance to movement, and under usual conditions only a part of the joints will move, whether the bolt tension is low or high. The movement is so difficult to control that there is probably no advantage in this respect in maintaining a low bolt tension within the limits of tension given above.

In this connection it may be noted again that for all purposes of the rail-joint the standard 1-in. high-strength bolts are of ample strength, even with 130-lb. rail. The greatest strain on the joint bolts results from eccentricity of bearing of head and nut against the bars due to obliquity of surfaces. With accurately finished extensometer bolts the increase in stress along one side of the bolt due to bending was considerable (see Table 15). With ordinary bolts and nuts the additional stress given by eccentricity of bearing and the resulting bending of the bolt will be the source of a considerable part of the maximum stress developed in the bolt.

51. **Fit and Play in Rail-Joint, Vertical Deflection of Joint Bars and of Rail-Joint under Load.**—In the tests in both laboratory and track, as in those reported in the Fifth Progress Report, it was found that the fit between the rail and joint bars varied considerably, and that with poor fit the vertical movement between rail and bar on application of load and also the deflection of the rail-joint as a whole was much greater than with well fitting bars. With increased vertical movement between rail and bar and the greater deflection of joint and the consequently greater inelastic downward movement at the rail ends when loaded comes a lessened magnitude of the moment developed in the rail-joint in the track (see Fig. 82, 84, and 88 of the Fifth Progress Report) and in the rail adjacent to it. It follows that there is also a greater depression of the joint ties under load and usually, too, a consequent lowness of the rail support. All of these detract from ideal conditions in the rail-joint and contribute to the defects found in track.

For what may be classed as well fitting joints the vertical movement between rail and joint bars at either the rail end or the bar end upon application of load averaged in the tests about .001 in., with a maximum vertical movement, .002 to .003 in. (see Fifth Progress Report, p. 286). The rail-joints with poor fit but tight bolts gave vertical movements as high as .01 in. With low bolt tension the vertical movement was much greater. Tightening the bolts generally reduced the vertical movement though not always. Vertical movement and play facilitate wear at the bearing points on fishing surfaces; conversely, with lack of vertical movement between rail and bar on application of load the wear is minimized and with hardened bars it is relatively small, and the conditions of deflection, depression of rail support, opportunities for resisting bending moment, and other functions of a rail-joint are enhanced. It may be repeated that a fit that gives the smallest vertical movement practicable between rail and bar at the critical areas of contact is a most important element of a satisfactory rail-joint.

The deflection of a well fitting rail-joint in a span of 48 in. tested in the laboratory with a load at mid-span ranged from 1.5 to 1.8 times that of the full rail when the bolts were tight. For low tension (2000 lb.) the ratio was 2.0 or more. With poorly fitting bars the ratio is considerably greater for both high tension and low tension. The bars used in the laboratory tests, even those called poor fit, had much less play than many that may be found in track. Play due to either original poor fit or wear is a source of increased deflection. The value of the moment of inertia of the section and the inclination of the neutral axis with respect to a horizontal line also affect the deflection of the joint. The test of the Muller rail-joint showed a deflection 3.6 times that of the full rail. The laboratory tests bring out the need of requiring a high standard of fit of bars as well as having excellence of design.

In the tests of track of the Chesapeake and Ohio Railway, for the rail directly opposite a joint the lines connecting the deflections in 66 in. for light and heavy loads (see Fig. 55) are approximately parallel to each other so that the deflection of the full rail may be called proportional to increase in moment in rail between the light and the heavy load. The deflection for the light load, however, is smaller or greater than this proportion, owing doubtless to variations in play and stiffness of support at and near a point opposite joint for which the deflection was taken. So far as the deflection of the rail-joint and rail is concerned, the trend of the deflections as shown by the line in Fig. 55 is roughly proportional to the moment developed at mid-section of joint bars, and even the lines which may be drawn connecting the points for medium and light loads would be found generally to be roughly parallel to the average line. The deflections of the rail-joints in 66 in. may be said, then, to be fairly proportional to the increase in moment developed in the joint regardless of how play and stiffness of the rail support may be varied. It was found, too, that the average deflection of the rail-joint in 66 in. is roughly $1\frac{2}{3}$ times the deflection of the full rail for the same moment.

52. **The Rail-Joint under an Advancing Load and Effect of Speed on Stresses and Bolt Tension.**—The laboratory tests on rail-joints under advancing load made by advancing both load and supports by increments of 6 in. toward and beyond the middle of the joint approximated in some ways the conditions of the joint in track. The distance from load to either support (24 in.) was shorter than the distance from wheel load to point of zero moment in the rail in track, which is ordinarily from 30 to 45 in. and includes two or more tie reactions at one side of the wheel load. The tests gave no evidence of any sudden changes in the deflections, movements, or stresses within the rail-joint that would produce undesirable accelerations or impacts as the load passes over the rail-joint. The bars of the rail-joints tested fitted the rails well enough to give a gradual development of stresses and vertical movements.

With the excellently fitting 38-in. N.Y.C. bar for 127-lb. rail used in the principal advancing load tests made, no moment was developed at mid-section of the bar when the forward support reached the rail ends, as is to be expected. At this loading, however, moment was developed at sections between mid-section of bar and the approach end (see moment distribution diagram for load at *B* Fig. 24). This is doubtless because with the excellence of fit the bar in this portion bends with the rail. With the load at 12 in. left of the rail ends and the forward support at 12 in. right of the rail ends the moment in the bar under the load is about half of that at mid-section. The distribution of the moment along the bar will be de-

pendent upon the fit between the bar and rail from point to point along the bar and the differences in the flexural curves of bar and rail. However this distribution may vary; a bar that fits the rail well along the length will give the peaked effect shown in Fig. 24 for the load at *F* (mid-section) and the accompanying high concentration of bearing pressure near the rail end.

The advancing load tests made with the shorter bars (Santa Fe 26-in. symmetrical bars and I.C. 24-in. angle bars, see Article 8), although not so complete as the tests made with N.Y.C. 38-in. bars, gave results which are in most ways similar to those obtained with the longer bars. The moments at eleven sections along the length of the Santa Fe bar for the various positions of the load are given in Fig. 26. The poorer fit between rail and right half of bar (see Fig. 14 for vertical movement between bar and rail) has produced some irregularities in the corresponding part of the moment diagrams. As would be expected, the extra moment developed in the first quarter and last quarter of the length of the bar because of the compelling curvature of the rail above the bar through this portion, as the wheel rolls along, is considerably less than in the 38-in. bar. As the bars used in the I.C. joint were somewhat worn and the fit for one of the halves of the bars was poor, differences in stresses were shown in the two halves. With a bolt tension of 20,000 lb. the extra magnitude of the moments in the first part and last part of the length was noticeable, but the hump was not present with a bolt tension of 2000 lb. and there must have been enough leeway so that the curvature of the rail did not act to bend the bar throughout these portions. With the low bolt tension the movement between bar and rail was increased considerably.

It should be noted again that with the long bar and to a slight extent with the short bar and with good fit a secondary load bearing may be developed on the top of the bar near the quarter point of the length as the wheel rolls over this region, evidently due to the downward curvature of the rail at this point being greater than that of the bar when the wheel is over or near this spot (see Article 8 "Action of a Rail-Joint under an Advancing Load").

In the tests on the Pennsylvania Railroad with the electric locomotive running at various speeds up to 90 miles per hour, the form of the record of the stress in the angle bar at mid-section and at 8 in. from mid-section corresponds to the form of the influence lines made up from the advancing load tests of the laboratory except as the several tie supports and the negative moment developed in the track modify the conditions. At the higher speeds the records were not always entirely definite and free from the effects of vibration.

The observed stresses in the joint bars in the tests on the Pennsylvania Railroad give important information upon the effect of speed of the locomotive on the stresses and moments developed in the rail-joints. The stresses and the moments at mid-section calculated from the observed stresses are given in detail in Tables 8, 9, 10, and 11. Since the condition of rail support differs considerably at the various joint locations, it has seemed well in making comparisons on the effect of speed to express the moment in terms of the average analytical moment in the full rail under static loading for points away from a joint—a value which is termed the joint moment ratio. The moment in the full rail at a speed of 5 miles per hour may be expected to be approximately the same as that developed in the rail if static load tests had been made with the given wheel loading. The values of the joint moment ratio for the several speeds used are recorded in Table 29. The values given (ex-

cept as otherwise noted) are the average of three or more runs and represent the average of the moments developed in the two bars of a rail-joint at mid-section under two drivers of electric locomotive 7850, which had a nominal driver wheel load of 37,500 lb. In further explanation, it may be stated that a joint moment ratio of .50 means that the moment developed at mid-section of the two bars of a rail-joint is .50 of the average moment developed in the rail itself at points along the track away from the rail-joint under static application of the same wheel loading,

Table 29

Effect of Speed on Joint Moment Ratio—Tests on the Pennsylvania Railroad at Claymont, Delaware

The Joint Moment Ratio is representative of the moment developed in the joint bars relatively to the average value developed in the rail at 5 miles per hour. Except as otherwise noted the values are the averages of three or more runs at the given speed.

Test	Joint Location and Bars	Speed in Miles per Hour				Remarks
		5	45	70	90	
(a)	4–4	.61	.63	.65	.65*	High bolt tension
(b)	4–4	.41	.50	.56	.68†	2000 lb. tension
(c)	4–4	.57	.63	.70		Bars sawed to 24 in.
(d)	4–5	.66	.72	.80†		High bolt tension
(e)	4–5	.69	.71			High bolt tension
(f)	5–5	.67	.65	.77		High bolt tension
(g)	1–1	.87	.78	.93	1.18*	High bolt tension
(h)	3–1	.85	.80	.86		High bolt tension
(i)	3–1	.84	.80	.70*		High bolt tension
(j)	11–11	.47	.48	.45		Track 1. Low bolt tension
(k)	9–9	.43	.52	.42		24-in. bars. Low bolt tension
(l)	3–3	.58	.54	.58†		High bolt tension
(m)	2–2	.42	.35	.38		Low bolt tension

*One run only. †Two runs.

which may be taken to be approximately the same as the same wheel loading will give at a speed of 5 miles per hour. It will be seen that the increase with speed for any of the tests is not large. In some tests there is a decrease, as in test (i). Naturally some irregularity is shown in the speed effect in some of the tests.

It should be noted that these tests were made on different joints, with differences in bolt tension, and with bars changed from one joint location to another and even with bars shortened from 38½ in. to 24 in., and of course with diverse conditions of tie support. Details of the condition of the various rail-joints are given in Chapter III "Tests of Rail-Joints on the Pennsylvania Railroad" but a brief statement of the conditions may be helpful here. In Table 29 the first number in the column headed "Joint Location and Bar" gives the location of the joint in the track (see

Fig. 33) and the second number gives the number of the joint at which the bars were originally located; thus, "4-5" in test (d) means that the test was made at joint location 4 with bars that were originally at joint location 5. The joint in test (a) (38½-in. angle bars) had been undisturbed for two months under heavy traffic and had an average bolt tension of 29,000 lb. In test (b) (the same joint) the average bolt tension had been decreased to about 2000 lb. and a .005 in. thickness gage could be inserted along the length of bar for 3 and 8 in. at the two ends of the bars and 2 to 6 in. at their middle. In test (c) the same bars had been sawed to a length of 24 in. and re-installed with a bolt tension of 28,000 lb. Tests (d) and (e) were made at the same joint location (4) with 38½-in. bars taken from joint location 5 and bolt tensions of 14,000 and 12,000 lb. The joint in test (f) (joint location 5, the same bars as in tests (d) and (e)) had remained undisturbed under heavy traffic for several months and the bolt tension was 14,000 lb. The bars of test (g) were laterally deformed and had been installed in joint location 1 only a few days and had a bolt tension of 12,000 lb. In tests (h) and (i) the bars from test (g) had been installed a short time at joint location 3 and were tested with bolt tensions of 23,000 lb. and 13,000 lb., respectively. Test (j) was made on track No. 1 on a joint with 38½-in. bars and an average bolt tension of 2000 lb.—a track with large traffic not in as good condition as track No. 4 where most of the tests were made. The joint location of test (k) was on track No. 4 away from the other test locations and the joint had not been disturbed for a long time. The bars were 24-in. angle bars and the bolt tension averaged 6000 lb. Test (l) (joint location 3) had symmetrical bars which apparently fitted poorly at the base. The symmetrical bars in test (m) (joint location 2) combined the detrimental effects of poor fit at the base and low bolt tension.

In making comparisons of the values of the joint moment ratios found at the various speeds for the several rail-joints used and for their different conditions, it is best to look for trends rather than specific ratios of increase with change of speed. Test (a) gives only a slight increase in moment and stress in the joint from 5 to 90 miles an hour. Test (b) on the same joint with very low bolt tension gives a much larger increase, but one of the three runs at 5 miles per hour gave a low value and the average ratio for the other two was .44, and one of the two runs at 90 miles per hour gave a moment at the second driver double that found on the other run thus indicating a considerable transfer of load to the opposite second driver on one run. The trend in test (b), however, is a considerably greater increase than in test (a). Test (c) gives over 20 per cent increase from 5 to 70 miles per hour. Test (d) with another set of bars at the same location gives a similar rate of increase. Tests (g), (h) and (i) with a pair of bars placed at two joint locations gives only a small increase to 70 miles per hour. The value 1.18 in test (g) in the one run at 90 miles per hour is 36 per cent greater than that found at 5 miles per hour. Tests (j) and (k) made on joints in two tracks which had not been disturbed for a long time gave little change from 5 to 70 miles per hour, as did joints 3-3 and 2-2 in tests (l) and (m).

Altogether the effect of speed on the stresses and moments in the joint bars was not large. For most of the tests with tight bolts the changes were not more than may be expected from variations in transfer of load from one wheel to others, independently of an increase from speed. Two of the tests showed an increase of 20 per cent from 5 to 70 miles per hour. The few runs at 90 miles per hour gave

a higher rate of increase, test (b) (low bolt tension) showing more than 50 per cent, test (g) 36 per cent, but test (a) less than 10 per cent. Although the effect of speed of the locomotive on the stresses developed in the rail in the tests at Claymont have not yet been reported, it may be said that the effect is not greater for the joints than may be expected for the rail in the same track if track is at least in good condition. Only a single run at 90 miles per hour in test (g) gave a moment in the joint bars greater than the average value to be expected in the full rail at points away from a joint for static loading or at a speed of 5 miles per hour.

It should be noted, of course, that the dynamic augment involved in the counterbalancing of steam locomotives and some forms of electric locomotives provides an additional source of increase of stress in rail and joint bars with increase in speed which was not present in these tests. With the electric locomotive used, a source of the variation in values of the stresses and moments at a given joint lies in the variation in wheel load applied at the joint in individual runs by transfer to the other wheel on the same axle or to a lesser extent to other wheels on the same rail. The transfer of wheel pressure to the companion wheel occurs when a greater lateral pressure is exerted against one rail than against the other, as when a locomotive oscillates laterally about a vertical axis. The oscillations were much more apparent at 90 miles per hour than at 70 miles per hour, and the variations are noticeable in the tests.

It will be seen from Table 29 that the conditions of rail support at a given joint location exercise a strong influence on the magnitude of the moment that may be developed in a joint if the different bars are well fitting. The values of the joint moment ratios and likewise of the corresponding moments developed, as well as the general increases with speed, for tests (a), (c), (d) and (e) are quite comparable, although the placing of a different pair of bars at the joint location in tests (d) and (e) results in somewhat larger values, which are somewhat the same as those found with these bars in their original location (test (f)). Tests (g), (h) and (i) at two other joint locations develop higher values. Tests (j) and (k) on track which had not been disturbed for some time and were found to have low bolt tension gave considerably smaller values.

It is well to remark that the tests were made on joints having bars that were not worn—even those that had been in track for some time under heavy traffic showed small wear and little play. The tie and ballast substructure was substantial and in good condition. The conditions, then, did not favor the development of impact in the joints nor the formation of high stresses in the bars, as may be expected in track in poor condition.

The changes in magnitude of the bolt tension (increase or decrease) at the time a driver passed over the joint were relatively small at the speeds of 5, 45, and 70 miles per hour on the three joints tested. See Article 22 "Changes in Bolt Tension Under Moving Loads" for details of tests and findings. The increases or decreases in the tension in the bolts in the joints tested (joints 4-5, 3-1, and 9-9) while under the load for the three speeds ranged from zero to 2000 lb., and in a few cases to 3000 lb., even with low tension in the bolts, values which are comparable to those found in static tests in the laboratory. The sign of the change in tension, whether positive or negative, was generally similar to those found in static tests in the laboratory. The change in tension here considered is distinct from the loss of tension

upon the repetition of passage of wheels after bars have been newly placed in track. The conclusion from the tests is that the magnitude of the changes in bolt tension during the passage of a train is not of great importance. It is to be expected that an even smaller change in magnitude will be found with symmetrical bars, since they do not have the same degree of tendency to swing inward at the middle and outward at the ends as have the angle bars.

53. **Miscellaneous Remarks on the Rail-Joint.**—In Chapter VI "General Discussion" of the Fifth Progress Report*, a discussion is given in some detail concerning the action of the rail-joint in track, the flexure within the rail-joint, the influence of the shape of sections, and other matters bearing on the design of the joint bar. Further consideration will now be given to the rail-joint.

1. Shape of the Section.

The analysis and tests given in the Fifth Progress Report permit comparisons to be made of symmetrical and unsymmetrical sections of bars. The angle bar form of section was originally adopted because a greater moment of inertia with respect to a horizontal geometrical axis for the limited fishing height may be obtained. Generally, however, the area below the horizontal axis is larger and less effectively placed than the area at the top. It was shown in the Fifth Progress Report that the angle bar section under vertical bending moment deflects downward and inwardly, with a neutral axis inclined to the horizontal, and consequently that the stresses resisting a given moment may be considerably greater than found by the ordinary assumptions of beam calculation. When there is little or no lateral restraint the inclination of the neutral axis of the angle bar at its middle is 45° or more and for some shapes part of the flange may be in compression instead of tension in resisting vertical bending moment. A well fitting angle bar held by tight bolts receives considerable lateral restraint, which modifies the flexural action of the bar, decreases the angle of inclination of the neutral axis, and thus limits the increase of stress above that obtaining with the neutral axis horizontal. In the region of mid-section, where the moment to be resisted is the greatest, values of the inclination of the neutral axis in well fitting angle bars with tight bolts in track were found to be as much as 25° to 35° giving an excess of stress of 20 to 35 per cent over those calculated with a horizontal neutral axis, while in joints under less favorable conditions the value reached 45° and the excess of stress 60 per cent. Worn bars and low bolt tension are conducive to the development of higher stresses for a given bending moment, but it should be noted also that in the track these conditions generally resulted in the development of a low moment in the joint, thus reducing its effectiveness in performing the functions of a joint. It is well to note, too, that these conditions markedly increase the deflection of the joint as a whole. Evidently excellence of fit and proper bolt tension are especially essential to securing satisfactory service in the angle bar form of rail-joint.

When the bar section is symmetrical with respect to the horizontal geometric axis, the application of a vertical bending moment results in a vertical deflection and the stresses are proportional to the vertical distance from this axis, even without lateral restraint, except for any twist that may be given from the bearing loads and reactions of the bar not being in the same plane. Symmetry of section is thus advantageous in promoting efficiency in flexural resistance, in avoiding lateral deflection from vertical loads, and in obviating the need for more than moderate bolt tension. With the limited fishing

* Proceedings, A.R.E.A., Vol. 31 (1930), p. 273.

height available and the limitations imposed by the presence of the wheel flanges it may not be feasible to design a truly symmetrical section that will have enough metal in the flanges to keep the resulting fiber stress down to a desired limit and meet the requirements of an economical section. Because of this and because the effect of slight dissymmetry is modified by a small amount of lateral restraint, it may be found advantageous to vary somewhat from true symmetry.

A study of the analysis and stresses of near-symmetrical joint bars given in Article 55 "The Design of Joint Bars" of the Fifth Progress Report leads to the conclusion that a dissymmetry that requires the application of a lateral restraining moment equal to one tenth of the applied vertical moment ($\frac{M_y}{M_x} = 0.1$) to maintain the neutral axis in a horizontal position may not be considered objectionable. A fair fit and moderate bolt tension will give this amount of lateral restraint to the bar, and even with looseness the additional stress developed under free bending is found to be less than 10 per cent. The relative value of the lateral restraint needed to maintain the neutral axis in a horizontal position may be obtained from the geometrical properties of the section by making $\tan \alpha$ equal to 0 in equation (47) of the Fifth Progress Report (equivalent to maintaining the neutral axis in a horizontal position), which then becomes $\frac{M_y}{M_x} = \frac{J_{xy}}{I_x}$, where I_x is the moment of inertia of the section with reference to the horizontal gravity axis and J_{xy} is the product of inertia with reference to the horizontal and vertical gravity axes. If the value of $\frac{M_y}{M_x}$ given by this equation is not more than 0.1, the dissymmetry will not be serious. The C. B. & Q. proposed section for 110-lb. rail and study section F for 130-lb. rail (see Table 31 and 32, Fifth Progress Report) are within the suggested limits of dissymmetry and to give a horizontal neutral axis require a lateral restraint equivalent to a lateral bending moment in the region of mid-section amounting to .08 times the vertical bending moment developed at the same section; with a restraint less than this amount the stresses are increased less than the 10 per cent named above. The Santa Fe near-symmetrical section for 130-lb. rail used in laboratory tests and in tests on the track of the Chesapeake and Ohio Railway, which has a section similar to study section F of the Fifth Progress Report, requires an even smaller restraint. The limit of 10 per cent for the lateral restraint needed to give a horizontal neutral axis results in small variations from the action of the symmetrical bar. Sections within this range of dissymmetry may be included in the term "symmetrical type of bar".*

In the matter of the deflection of the bar and the rail-joint in track, for bars of the symmetrical type the full value of the moment of inertia of the section with reference to the horizontal gravity axis may be used in determining vertical deflections and making comparisons of the stiffness of joint bars without serious error, while for the usual angle bar a value of two-thirds of the moment of inertia of the section or less has been found applicable throughout the middle part of the length of the bar. The stiffness of the symmetrical bar as compared with the angle bar is thus considerably greater than is indicated by a direct comparison of the moments of inertia.

* It should be noted that while exact symmetry is not essential any dissymmetry should be such as to make the lateral component of an oblique deflection caused by a vertical bending moment to be directed inwardly of the joint rather than outwardly. It may be said further that as the lateral restraint of the bar in the rail-joint referred to is not under control some obliquity of deflection of the joint bar may occur (even with exact symmetry, due to conditions of fit between bar and rail) and that therefore some variation from vertical movement must be expected. However, a dissymmetry less than the limit of 10 per cent will have advantages.

The Continuous joint bar by means of its reflexed flange gives an opportunity to place additional metal well away from the horizontal geometrical axis of the section and thus to develop a greater strength in the bar, but it should be understood that the reflexed flange is not fully effective in giving the resistance to flexure that is ordinarily assumed for sections acting integrally and the stiffness of the bars in the joint will not be proportional to the moment of inertia of the section. The reflexed flange involves the use of a different tie-plate at the joint and a lowering of the level of the joint ties.

Regardless of the general type of joint bar and considering the limitations of the fishing height, a well designed section requires that the top flange or head be large enough to balance the lower flange as far as is practicable and also that the areas of the two flanges be so placed as to minimize dissymmetry of section with respect to the horizontal axis such as that found in the angle bar and the Z-bar section. In the design of the flanges of the joint bar, the size of the bolt heads and nuts and their position may make limitations.

2. Fit and Longitudinal Form.

In the discussions of the rail-joint emphasis has been placed on the importance of close fit between bar and rail in reducing play and wear and increasing markedly the effectiveness of the joint in moment and deflection resistance and thus decreasing the amount and cost of maintenance. The tests have shown that load bearings and reaction bearings between rail and bar on application of wheel loads are developed at certain points along the length of the bar for both positive moment and negative moment. For positive moment the load bearing forces usually are found at and near the rail ends and the resultant reaction forces at two points on the base of rail in each half of the length of the bars (see Fig. 1, 82 and 83). It seems well to consider the position and relative magnitude of these forces and to consider whether it is possible and proper to further control their position and magnitude. In the present discussion new or unworn bars are considered.

In Fig. 84 suggested positions of controlled bearing contacts along the top and bottom of the bar are shown for three lengths of joint bars; it should be borne in mind that the amount of the relief desired is greatly exaggerated in the figure. It is evident that for positive moment it is desirable to have close fit at the best place along the load bearing area at the top of the bar. It is also evident that it would be well not to have load bearing contact right at the rail end nor for a short distance back of it—this to prevent concentration of pressure on the bar close to the rail end where the bar is curved but the rail is straight and makes an angle with the direction of the curve of the bar while under load, and also to avoid the cutting action of a sharp edge at the extreme end of the rail. This means that freedom from load bearing contact for a short distance back of the rail end (say, a half inch) would be advantageous. Such a gap between the bearing areas of the two rails, too, would leave some opportunity for local adjustment. Next to this gap at the middle of the bar each way a length of 2½ inches or so for the top load bearing contacts would seem to be sufficient. Away from these areas of contact a freedom from contact for some distance along top of the bar until a controlled end bearing is reached would appear to be advantageous for the reason that the designed bearing near the rail end would continue to be maintained even after some wear occurs or even when there are slight variations in fit. The relief from contact in the intermediate region would permit lateral springing action to be developed in the bar by the bolt tension to maintain the bars in proper position with respect to the rail.

With reference to the reaction bearing contacts on the lower fishing surface, it should be pointed out first that with a bar that fits all along its length the lesser curvature of

the rail toward its end under positive moment results in the base of the rail at its end being directed away from the bottom of the bar and thus there will be a freeing of bearing contact at the lower fishing surface close to the end of the rail. The moment distribution diagrams for such bars show that an interior reaction bearing contact (see Fig. 82 and 83) exists a short distance back from the rail end, its resultant or centroid being generally about 4 in. back from the rail end, or somewhat more. This closeness to the position of the top load bearing pressure (4 in. or so longitudinally between the resultants of the bearing pressure and the reaction) is necessarily accompanied by a large magnitude in the top bearing pressure, sometimes excessively large, and this condition may also be a contributor to the wearing back along the top fishing surface of the bar.

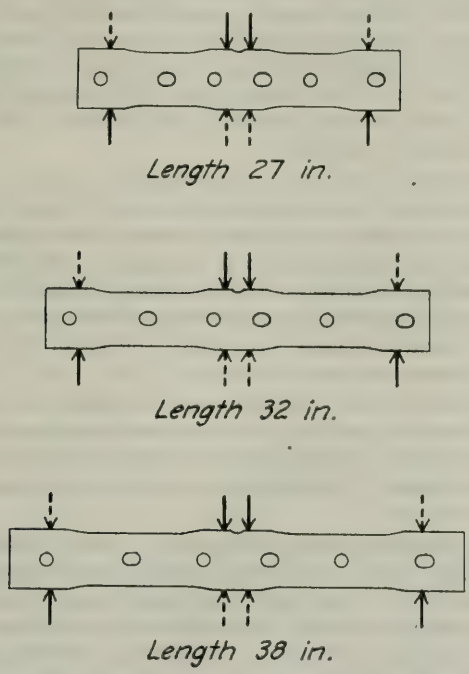


Fig. 84.—Position of Contacts and Reliefs for Controlled Bearings.

If a length of base contact of say only 2 in. each way from mid-section were provided for the bearing contact resistance to negative moment, a relief of the base contact for some distance beyond would obviate the development of any reaction force in this region and in this way a considerable reduction in the magnitude of the load bearing pressure at the top fishing surface would be made. The base bearing contact for positive moment would then be provided along the remainder of the length of the bar.

For resisting the negative moment, bearing contact along the top of the bar well away from the middle part of the length, perhaps corresponding to the end reaction bearing suggested for the bottom of the bar, should be provided, which together with the provision for bottom bearing close to mid-section will give fishing contacts for forces

that resist negative moment (see the loads and reactions shown by dotted lines in Fig. 84).

The control of the load bearing contacts and reaction bearing contacts at definite places along the length of the bar may be expected to locate the bearing forces between bar and rail at advantageous positions for both positive and negative moment. Such an arrangement will avoid the difficulties and secure the gains referred to in the last three paragraphs. The resulting fit between the bar and the two rails at the contact areas will be improved over that otherwise available with the ordinary variations in bars. Some minor variations in fishing height at the two rail ends may be overcome by the bending and twisting of the bars in tightening the bolts. When wear or other change occurs, the tightening of the bolts may bring back contacts at the same places so that proper bearing conditions will be renewed. As mentioned previously, tension in a bolt placed at the middle of the non-fishing part of the bar will develop a spring having some travel which will be useful in holding the bar in place against wear and lateral movement. On the other hand, the greater length of bar taking flexure with the controlled bearings will result in some increase in the deflection of the rail-joint, unless counteracted by the better fit obtainable.

The desired limitations of reaction and load bearing contacts can be effected by forming or deforming the bar vertically or laterally or both. Care should be taken that the relief from bottom bearing contact should continue closely enough to mid-section to ensure freedom from the development of a reaction force near mid-section, as is seen generally to exist in Fig. 82 and 83 and in other tests that have been made, and yet leave a sufficient length of contact to make adequate provision for base bearing contact in resistance to negative moment. The lateral stiffness of the lower flange of the angle bar makes this precaution more important.

Whatever means are used in shaping the bar to restrict the bearing contacts to specific locations, the control must be such as to ensure relief from reaction and load bearing contacts except at the designated places. The transition to and from bearing contacts should not be abrupt. The clearance in the relieved portions need not be large, better not more than .05 in.

The form of the Muller rail-joint tested provides reaction bearing contacts only for a few inches at the ends of the bar and thus minimizes the magnitude of the load and reaction forces developed in the bar under the positive moment, an advantageous condition. At the same time, in changing from positive to negative moment a considerable upward movement in a span of 48 in. was made (.15 in.) before negative resisting moment was developed, and under the negative moment the resultants of the load and reaction were so close together horizontally that the magnitude of these bearing forces was relatively very large. Under these conditions, too, the interval between the release of positive moment and the lifting of the rail to where negative moment would begin to be developed is so large that for track having moderate or high stiffness of rail support the construction would fail to possess the usefulness of negative resistance at the rail-joint.

The caution against the high initial stress developed in the Muller joint bar by tightening the end bolts, suggests also the need of caution in regard to more than small vertical or lateral curvature of any bar (vertical or lateral camber, if the term camber may be applied to lateral deviation from straightness of bar). With even what may seem to be a moderate variation from straightness, the stress put into the joint bar by tightening bolts has been found to develop high installation stresses, which when added to the

stress due to loading (especially where the conditions of the rail support are conducive to high negative moment) may develop excessive bending stresses. Even though the curvature may give desirable characteristics, it is something which needs careful control, especially with the stiffer bars, and this control may well be embodied in specifications and inspection.

A somewhat similar condition exists in bars which are worn for some distance away from mid-section. The tightening of the inner bolts bends the middle of the length of the bar laterally and twists its top inwardly and in effect lifts the middle of the bar so that the upward and inward moments developed result in initial tensile stress in part or all of the top flange. If the tie supports at and near the joint are in such position as to produce a relatively high negative moment in the joint bars upon the passage of a train, the combination of the high initial tensile stress in the upper flange and the tensile stress of the negative bending moment will result in the formation of relatively high tensile stresses in the top flange. This combination is a source of the breakage of bars from the top, which is not uncommon.

3. Size and Spacing of Joint Bolts.

As already noted, considering the limitations of usefulness in the total tension applied by a bolt, a diameter of 1 in. in a bolt that is properly heat-treated may be called adequate, even taking into account possible high bending stresses due to eccentricity of bearing on head and nut. A larger size, with the accompanying increase in the dimensions of head and nut, is likely to interfere with the placing of desired areas in the flanges of the bars.

It is appreciated that within the range of bolt spacings ordinarily used no large differences in effects will be found. However, certain comments on bolt spacing will be made without giving specific dimensions. The end bolts for either short or long bars and with either four or six bolts may well be placed as close to the ends of the bar as will not result in breakages through the bolt holes; the shorter the distances from the end the less the outward curl of the end when the joint is loaded—the part of the bar more than 2 in. beyond an end bolt adds little to the effectivness of the bar. The inner bolts may well be placed as close to mid-length of the bar as will not result in breakage of rail or bar through the bolt hole. A close spacing between the two inner bolts will facilitate taking up wear near mid-length, though close fitting along the top fishing surface beyond the inner bolts will interfere with such adjustment. With a bar having controlled bearing contacts and six bolts (see Fig. 84), the intermediate bolt holes may well be half way between the inner edge of the end bearing contact and the edge of the middle bearing contact. This position will make the intermediate bolt closer to the inner bolt than to the end bolt. Illustrative spacings are shown in Fig. 84 for three lengths of bars. For bars without controlled bearing contacts an equal spacing from intermediate to end bolts and to inner bolts would be satisfactory. The remarks apply to both angle bars and symmetrical bars and also to joint bars with straight or continuous fishing surface and to those with controlled bearing areas, though the angle bar with controlled contacts may not develop as much lateral restraint as it will with continuous fishing surface. Slight variations in bolt spacing are not important—a movement to uniformity in practice would be advantageous.

The vertical position of the bolt holes may well be chosen low enough to best permit placing a sufficiently heavy head of bar to make a well-balanced design (for a large well-designed head is essential for strength and stiffness) and yet to facilitate nut clear-

ance. The center of the bolt hole need not be at the gravity axis of the rail or the bar. It will be seen that the design of the joint bar and the position of the bolt holes with respect to the web height of the rail are interrelated. The D. L. & W. drilling for 130-lb. R.E. rail, which is at mid-height of web, gives opportunity for maximum area of bar flanges for a bar that is reversible in vertical position and has two sets of fishing surfaces, but a much stiffer and stronger bar is possible if not made reversible. The lower drilling of the C. & O. Railway and A.T. & S.F. Railway (2¾ in. above base of rail, 5/16 in. below mid-height of web) will not permit the design of a reversible bar, but it does give opportunity for a stiffer non-reversible bar than is possible with the D. L. & W. drilling such as is exemplified in study section F. Similarly the lower drilling of the N.Y.C. 127-lb. rail, which is 7/64 in. below mid-height, gives abundant space for heavy top and bottom flanges for the bar. The drilling of the newly adopted 131-lb. R.E. rail, which is 1/32 in. below mid-height of web, is adapted to a reversible form of bar as well as to a non-reversible form—with a lower drilling study section G hereafter shown could have been made somewhat heavier. In general for any rail section, a drilling that is, say, ¼ in. below the line of mid-height has advantages in that a heavier top flange may be provided.

4. Length of Joint Bar.

The tests confirm the statements made in the Fifth Progress Report that the length of the so-called short bar gives adequate opportunity for development of resisting moment. In either short bar or long bar, if the load and reaction bearing areas are not controlled or restricted, a large part of the moment is developed within 4 to 6 in. of the middle of the length, especially with well-fitting bars and moderate or high bolt tension. A length of 27 in. has been found to give satisfactory spacing for six bolts. A length of 38 or 39 in. upon application of load gives a somewhat smaller vertical movement between rail and bar at the bar end as compared with short bars having the same general qualities of fit, but it has not been found to decrease the vertical movement at the rail end—vertical movement at this point depends largely upon the fit between bar and rail for a given joint. The longer length does not aid in reaching a tie support—it is the rail and not the bar which is supported by the tie-plate and tie. With either length the bars should have a sufficient degree of hardness to give proper resistance to wear. No great advantage in a length of joint bar longer than 27 in. is apparent from the tests. If a longer length were wanted to give greater spring travel in a joint bar with controlled fishing contacts, a length of 32 in. would seem adequate for this purpose. The metal in the additional length to make 38 or 39 in. may well be used in getting a heavier section of bar.

5. Lateral Bending.

In the discussion in the Fifth Progress Report it was concluded that allowance should be made on straight track and light curves for a lateral bending moment equal to 10 per cent of the maximum vertical moment ordinarily developed and that the lateral bending moment will not reach 20 per cent under ordinary conditions of traffic and track, and also that for lateral bending moment greater than 10 per cent there will be a sufficient margin of safety in the resistance of the ordinary rail-joint to prevent failure in the joint in ordinary good track. It was concluded from the tests that a bolt tension of 5,000 lb. or more will bring the joint structure into a degree of integral action sufficient to greatly decrease the lateral bending stresses in the joint bars below those developed when the bars resist bending by individual beam action alone, as is found to be the case with very low bolt tensions. With the bolt tension of 5,000 lb. or more it

was found that for a lateral bending moment equal to 10 per cent of the maximum vertical bending moment the stresses developed in the joint bars, either angle bars or symmetrical bars, will not greatly tax the strength of the bar, especially as the fiber developing the highest vertical bending stress will not ordinarily be the one that develops the highest lateral bending stress, and thus that the maximum stress in combined vertical and lateral bending will be less than the sum of the maximum bending stresses for the two bending actions.

54. **Design and Comparison of Joint Bars.**—In the effort to approach toward some of the conditions of an ideal rail-joint—a stiffness similar to that of the full rail and thus the same depression of rail at the joint as elsewhere, and also adequate strength—it is well to formulate some of the qualifications and characteristics of the joint bar that may be expected to contribute to optimum conditions in the rail-joint in these respects. Certain desirable features may be named—fit, adequate stiffness, sufficient strength, moderate magnitude and intensity of bearing pressure between rail and bar, minimum wear, and satisfactory section and longitudinal shape of bar. Other features, perhaps commonly accepted, need not be discussed here.

1. Discussion of Qualifications.

Fit between bar and rail at certain important points along the bar (and with it lack of play) is essential to proper stiffness of joint, to smallness of deflection, and to the minimizing of wear—in fact it ranks high among the qualifications for good joints. The excellence of fit in the joint bars of the Delaware, Lackawanna and Western Railroad in the tests described in the Fifth Progress Report, the small value of the movement between bar and rail on application of load (the sum of the movement at four points of a bar—two ends of the bar and end of two rails—ranging from .002 to .005 in.), and the smallness of the vertical deflections are one of the sources of the excellence of service given by the rail-joints in this track. Excellence of fit may well be considered a most important requirement for joint bars. Specifications and inspection should stress close requirements even at the expense of some increase in cost.

It should be accepted as a principle that the stiffness of the track at the rail-joint (resistance to depression under load) should be as near to that of the full rail as is practicable. Besides excellence of fit, stiffness of the bar itself is important in obtaining this result. The need of gaining more stiffness in the joint bars may be judged from the fact that many forms of bars in effect have a stiffness in two bars less than 20 per cent of that of the full rail and that at best but little more than 40 per cent may be attained.

Many joint bars are low in available strength. In the heavier rails, having relatively greater fishing heights, it is not difficult to design a section that will give adequate strength. For calculations and comparisons the magnitude of bending moment used in the discussion in the Fifth Progress Report, 400,000 in.-lb. in two bars, may be considered as applicable to the common conditions of well-kept track with ordinarily heavy rolling stock, and the corresponding stress of 35,000 lb. per sq. in. as a proper working stress—both applicable whether the weight of rail is medium or heavy. It may be added that the strength of joint bars does not need the same improvement as the fit, the stiffness, and the resistance to wear. Poor fit and wear of bar may result in breakages which are largely due to causes that increase the stresses beyond those due to bending moment.

The magnitude of the bearing pressures between rail and bar at certain areas along the length of the bars is high. The data of the laboratory tests on unused joint bars

give evidence of a load bearing pressure near the end of one rail amounting to as much as 80,000 lb. on the two bars (40,000 lb. on one bar, see Fig. 82), and a similar pressure applied by the contiguous rail. Although the area of the load bearing contact resisting this pressure is uncertain, the intensity of pressure will be great and the opportunity for abrasion of metal with the accompanying movement of rail on bar will be large. A source of the high load bearing pressure is the closeness of one reaction bearing to the end of the rail—frequently 4 in. away—making the arm of the moment produced by this reaction relatively small. The removal of this reaction to a position a greater distance from the rail end, which may be effected by properly controlling the position of the reaction contact areas, will reduce the magnitude of the bearing pressure. Such control will be useful also for other purposes.

Wear along the upper fishing surface is increased by high magnitudes and concentrations of bearing pressure. Abrasion accompanies the slipping movement of rail over bar back and forth as a wheel rolls over the joint—a movement due to the differences in the amount of shortening of the fibers on the top surface of the bar and of those on the under side of the head of the rail in the flexure of the joint under load, as well as to the movement of rail head along the top of the bar due to the longitudinal thrust of the rolling wheel, especially on the receiving rail. Although the movement is small the abrasive action under high concentrations of pressure will be troublesome with mild metal. Play between bar and rail will also increase the wear. Suitable hardening treatment of the metal of the bar or of the parts in the region of the load bearing area will remedy the trouble. Control of the position of the reaction bearing areas will also be helpful. Usually little wear is found at the reaction contact areas (the contact areas being greater and the strains less) and also at the load and reaction bearing areas for negative moment, where the pressures are smaller and the strains less.

In designing the bar section, it is obvious that the following should have consideration: (a) an economical arrangement of metal over the section to secure the requisite stiffness and strength; (b) an approach to symmetry of section with respect to the horizontal axis; (c) for some conditions also an approach to symmetry with respect to the vertical geometrical axis; and (d) a form of section that will be favorable to manufacture. An allowance of space for wheel flanges and for bolts and nuts may limit the size of the top flange. Requisite stiffness and strength relative to that of the rail will involve a study of the upper limits of sections to fit the available space. Distorted I sections within allowable limits of dissymmetry will generally give the best approach to filling requirements for stiffness and strength, though for some conditions a section that has symmetry both horizontally and vertically is preferable, especially for reversibility in the joint. A form which is favorable to uniformity in the finished bar after passing through the rolling and cooling processes has advantages. For rail sections of about the same area, as, for example, the 130-lb. P.S. rail and the 131-lb. R.E. rail, which have effective fishing heights of about 3.9 and 4.7 in., respectively, the greater fishing height of the higher rail furnishes the opportunity for designing a much stronger and stiffer bar. Likewise, for two sections with similar proportions, the heavy rail will have advantages over the lighter one in the strength and stiffness of the joint bar that may be designed. For the lightest weights of rail some form of angle bar may best fit the limitations of the rail section.

2. Comparison of Sections.

Values of certain geometric properties of rail sections and sections of joint bars (including several study sections) are given in Tables 1 and 2. In making comparisons of stiffness and strength of bars as affected by their form of section, recourse may be had to

their moments of inertia and section moduli (or instead of the latter the corresponding stress values for any given bending moment), both on the assumption of a horizontal neutral axis and by making suitable allowance for the effect of dissymmetry of section in the track in the case of angle bars. In Table 30 (besides certain properties of sections, which are in the usual units) are given the ratios of the sectional area of two bars to that of the rail $(\frac{A}{A_0})$, the ratio of the vertical stiffness of two bars to that of the rail as represented by the ratio of their moments of inertia with respect to a horizontal axis $(\frac{I}{I_0})$, and the ratio of the calculated or analytical extreme fiber stress in two bars to that in the base of rail when resisting a given vertical bending moment on the assumption that the neutral axis of the bars remains horizontal. There are also given estimated values of the stiffness ratio and the stress ratio intended to represent values which are available in well-kept track, I' being the estimated effective moment of inertia and s' the corresponding fiber stress likely to be found in track service for a given vertical moment by reason of conditions of dissymmetry of section under the lateral restraint usual in well-kept track. It should be added that the effective moment of inertia used in estimating the relative vertical stiffness and relative stress of the unsymmetrical bars under track conditions is the same as K_x given in equation (57) of the Fifth Progress Report.

The decrease in stiffness ratios and the increase in stress ratios for the unsymmetrical bars given in Table 30 for track conditions over those based on a horizontal neutral axis were obtained from the data of tests in this report and also in the Fifth Progress Report for the track of several railroads on which tests were made. Discussion on these matters may be found in Chapter VI "General Discussion" of the Fifth Progress Report and particularly in Article 54 "Influence of Shape of Section of Joint Bars upon Resistance to Flexure". The values of the tangent of the angle of inclination of the neutral axis for unsymmetrical sections in these track tests ranged from .3 to 1.0. The values of the ratios $\frac{I'}{I_0}$ and $\frac{s'}{s_0}$ given in the table are the estimated average values to be found in well-kept track; they may be considered as representative of track in general good condition. With low bolt tension and poor fit of bar the values of the ratios would be poorer; on the other hand more favorable conditions may give better values.

The joint bars named in Table 30 are for rail ranging in weight from 90 to 152 lb. per yard. The angle bars referred to in the table except the B. & O. bar have been tested in track. They may be considered to represent the heavier forms of angle bar for the given weights of rail; the B. & O. bar shown in section in Fig. 85 is especially heavy. The C. & N. W. skirtless, the C. B. & Q. proposed I section and the A. T. & S. F. joint bars may be considered to be of the near-symmetrical type. The sections of these three and of study sections C, E and F are given in Fig. 117, 119 and 120 of the Fifth Progress Report. Study section F is quite similar to the section of the Santa Fe symmetrical bar tested on the Chesapeake and Ohio Railway, which is shown in Fig. 3. Study section G* and Pennsylvania symmetrical bar F-4 for 131-lb. R. E. rail and Pennsylvania symmetrical bar F-1 and study section H for 152-lb. P.S. rail are given in Fig. 86 and 87. Study section I* for 112-lb. rail is shown in Fig. 85. The section shown by the full line and the values given in Table 30 are based on a rail drilling at middle of the web

* Since this report was submitted study sections G and I have been modified from the form given in Fig. 85 and 86 by removing a narrow vertical strip from the outside of the outer lower flange. The properties of the revised sections are somewhat different from the values given in Table 30.

TABLE 30

Ratios of Properties of Sections of Joint Bars to the Corresponding Values for the Rail

A_o, I_o and s_o are the sectional area, moment of inertia and fiber stress for a given bending moment, respectively, for the rail, and A, I and s the corresponding values for two bars on the assumption of a horizontal neutral axis. I' and s' represent values available under track conditions. For the symmetrical type of bar, I' is considered to be approximately equal to I.

Name	Rail Lb. Per Yard	Sectional Area			Stiffness Ratio				Stress Ratio	
		Rail	Two Bars	$\frac{A}{A_o}$	Rail I_o	Two Bars I	$\frac{I}{I_o}$	$\frac{I'}{I_o}$ trk.	$\frac{s}{s_o}$	$\frac{s'}{s_o}$ trk.
I. C.*	90R-A	8.82	8.92	1.01	38.7	16.1	.41	.31	2.13	2.4
N. Y. C.	105 NYC	10.26	9.00	.88	50.0	19.3	.39	.25	2.27	2.9
N. C. & St. L.	110 RE	10.82	10.38	.96	57.0	22.1	.39	.26	2.17	2.6
C. & N. W.	110 RE	10.82	8.72	.81	57.0	15.1	.26	.24	3.03	3.0
C. B. & Q.	110 RE	10.82	10.38	.96	57.0	19.2	.34	.34	2.33	2.3
A. T. & S. F.	110 RE	10.82	9.52	.88	57.0	16.6	.29	.27	2.63	2.7
Study section I	112 RE	11.05	11.70	1.06	66.1	25.3	.38	.38	2.10	2.1
N. Y. C.	127 NYC	12.48	12.02	.96	83.7	34.5	.41	.28	2.38	2.8
Study section C	127 NYC	12.48	12.30	.99	83.7	33.2	.40	.40	2.13	2.1
D. L. & W.	130 RE	12.71	9.54	.75	77.4	16.5	.21	.21	3.38	3.4
B. & O.	130 RE	12.71	14.78	1.16	77.4	41.3	.53	.35	1.63	2.1
Study section F	130 RE	12.71	18.20	1.04	77.4	29.2	.38	.38	2.08	2.1
Santa Fe Sym.	130 RE	12.71	12.68	1.00	77.4	26.7	.34	.34	2.31	2.3
Penn. L-3	130 PS	12.70	12.68	1.00	72.8	33.1	.45	.33	1.79	2.2
Penn. F-4	131 RE	12.86	10.40	.81	88.6	24.4	.28	.28	2.85	2.9
Study section G	131 RE	12.86	14.08	1.09	88.6	37.1	.42	.42	1.93	1.9
Penn. F-1	152 PS	14.88	12.52	.84	128.6	36.9	.29	.29	3.00	3.0
Study section H	152 PS	14.88	15.16	1.02	128.6	55.2	.43	.43	2.00	2.0

*The inclination of the neutral axis of the I. C. bars tested in track in their original condition ranged from about 15° to 45°, with resulting corresponding $\frac{I'}{I_o}$ of .37 to .18 and $\frac{s'}{s_o}$ of 2.2 to 2.7. The maximum inclination was found with worn bars and low bolt tension.

height. If the center of the bolt hole were lowered to 2⅞ in. above the base, a better balanced upper flange of the bar shown by the dotted lines in Fig. 85 could be designed having I for two bars 25.9 and $\frac{I}{y}$ 10.9.

It will be noted from the table that the areas of two bars range from .75 to 1.16 of the area of the full rail. Several of them are close to 1.00.

The ratios of the stiffness of two bars to that of the full rail as indicated by their respective moments of inertia with account taken of the effect of dissymmetry upon the

stiffness for unsymmetrical bars give a means of judging of the stiffness of the joint bar in the joint; thus for conditions in the track the ratio $\frac{I'}{I_0}$ of .40 means that the two joint bars in the track together have a stiffness equal to .40 of the stiffness of the full rail, the relative deflection under the same bending moment being the reciprocal of this — 2.50

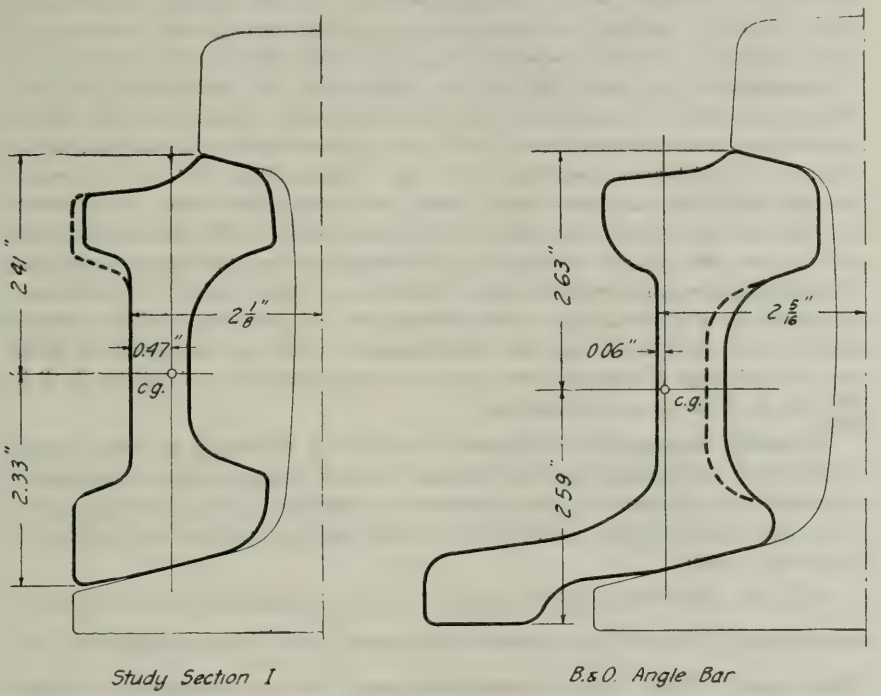


Fig. 85.—Sections of Joint Bar for 112-lb. R.E. Rail and of Angle Bar for 130-lb. R.E. Rail.

times as great. As the tests of angle bars on the track of the several railroads gave an average inclination of the neutral axis of 25° to 30° (the range being from about 15° to 45°), the resulting $\frac{I'}{I_0}$ for the angle bar joints averages about two-thirds of the corresponding $\frac{I}{I_0}$. The values of $\frac{I'}{I_0}$ in the table are considered to be representative of the conditions in ordinary good track. With well fitting bars of the symmetrical type the tests indicate that the values of $\frac{I'}{I_0}$ in track may be taken as equal to $\frac{I}{I_0}$.

It will be noted that the N.Y.C. angle bar for 127-lb. rail has ratios of $\frac{I}{I_0}$ and $\frac{I'}{I_0}$ of .41 and .28, respectively, and similarly the Pennsylvania L-3 angle bar for 130-lb. P.S. rail, of .45 and .33. The I. C. angle bar for 90-lb. rail has a considerable range in the

ratios for track conditions, .41 for a horizontal axis and .18 to .37 for track conditions, and a value of .31 may be considered applicable under ordinary good track conditions. The N. C. & St. L. angle bar for 110-lb. rail has a ratio of .39 for horizontal axis and .26 for the ordinary good track conditions. The C. & N. W. skirtless bar (a light bar with light flanges) with good fit and tight bolts has nearly as great a stiffness in track as is indicated by calculations with a horizontal neutral axis. The C. B. & Q. proposed I section for 110-lb. rail may be expected to give a stiffer joint than the preceding bar. Study sections C, E and F (symmetrical type) have good stiffness ratios. The D. L. & W. symmetrical bar for 130-lb. R.E. rail has a light section (the newer rollings are somewhat heavier) but it is reported to have given satisfactory service, due partly to the extreme care taken to obtain close fit and to the decreased spacing of the joint ties as well as to the high-grade condition of the track. Section Penn. F-4, a Pennsylvania joint bar for 131-lb. rail is not a heavy section, but it has a good form. Study section G for the same rail is a stiff bar. Study section H for the 152-lb. P.S. rail indicates what may be done with a heavier section than the Pennsylvania bar, the stiffness ratio being .42 notwithstanding the greatly increased rail stiffness. Study section I for the newly adopted 112-lb. R.E. rail also has a high stiffness ratio, .38; the value of the moment of inertia of two bars, 25.3, brings out the advantages of the new rail section in giving more vertical space for the bars—the values for symmetrical bars of the 110-lb. R.E. rail given in Table 30 are 19.2 and 16.6.

In making comparison of the stiffness of joint bars it should also be borne in mind that the track tests have shown that joint bars in track having a marked inclination of the neutral axis, by reason of either dissymmetry of section or poor fit or wear or improper bolt tension, develop small bending moments and are inefficient in exercising the functions of a joint.

The stress ratios for any given moment (a ratio of extreme fiber stress in a bar to stress in base of full rail, $\frac{s}{s_0}$ for neutral axis horizontal, and $\frac{s'}{s_0}$ for estimated track conditions) given in Table 30 have a considerable range. For the assumption of a horizontal neutral axis the extreme fiber stress in the bars ranges from 1.63 to 3.38 times that in base of rail and for average track conditions the estimated ratios range from 1.9 to 3.4. For the study sections, the stresses will range from 1.9 to 2.1 times the stress in rail. In this connection it should be noted that the values of the section modulus for all the joint bars given in Table 2 are based on the uppermost fiber except the Santa Fe symmetrical bars and study section H, which refer to the lowermost fiber. A comparison of the stresses developed in the bars used with the several weights of rail will show, of course, very great differences. For a moment of 400,000 in.-lb. in two bars (the value used in the Fifth Progress Report for design purposes), the calculated extreme fiber stress in the joint bars in pounds per square inch for track conditions on the assumption that the elastic limit is not exceeded are as follows: I. C. (90 lb.), 63,000; C. & N. W. (110 lb.), 60,000; C. B. & Q. (110 lb.), 46,000; study section I (112 lb.), 38,000; N.Y.C. (127 lb.), 41,000; study section C (127 lb.), 31,000; D. L. & W. (130 lb.), 53,000; B. & O. (130 lb.), 33,000; study section F (130 lb.), 33,000; Penn. L-3 (130 lb.), 37,000; study section G (131 lb.), 28,000; Penn. F-4 (131 lb.), 42,000; Penn. F-1 (152 lb.), 33,000; and study section H (152 lb.), 22,000.

With reference to the relative stiffness of joint bars, it is well to note that the maximum variations from a horizontal neutral axis in the unsymmetrical bars are confined to a short distance along the middle of the length of the bar (perhaps 6 or 8 in.) but this part of the length carries by far the greatest moment and consequently has by far the greatest curvature, and this curvature has a marked effect on the total deflection of the bar and upon the total deflection of the rail-joint as a whole. Outside of this middle region the bar has relatively little curvature (nearly a straight line) and the slope of the outer parts of its length is dependent almost wholly on the curvature of the middle portion. The values of the ratios in the table based upon the estimated effective moment

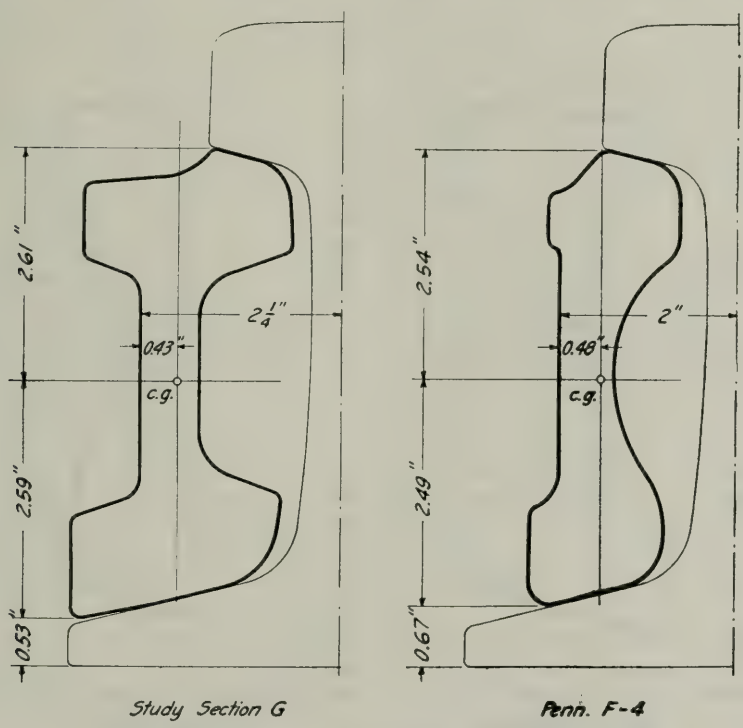


Fig. 86.—Sections of Joint Bars for 131-lb. R.E. Rail.

of inertia of the bar in track may then be taken to represent fairly well the relative deflections of the joint bars.

It should not be overlooked that the deflection of the joint bars is only one element in the deflection of the rail-joint. Play between bar and rail, although seemingly a small matter, quite commonly influences greatly the deflection of rail-joint and the consequent distribution of reactions among the ties at and near the joint. Proper fit in the joint, and continued fit, should be emphasized as important elements in securing high-grade rail-joints.

55. **Spacing of Joint Ties.**—The conclusion that a decreased spacing at the joint ties below the normal spacing has a great influence toward securing no greater depression at the rail-joint than elsewhere along the rail and in avoiding low joints in well ballasted track should receive favorable consideration. Due to the lesser stiffness of the rail-joint as compared with the full rail and also to any play between rail and joint bars, a greater demand is made on the rail support at the rail-joint than elsewhere when the support is uniformly stiff along the length of the rail. This decreased tie spacing is an effective agency in improving conditions up to the point where the greater stiffness of

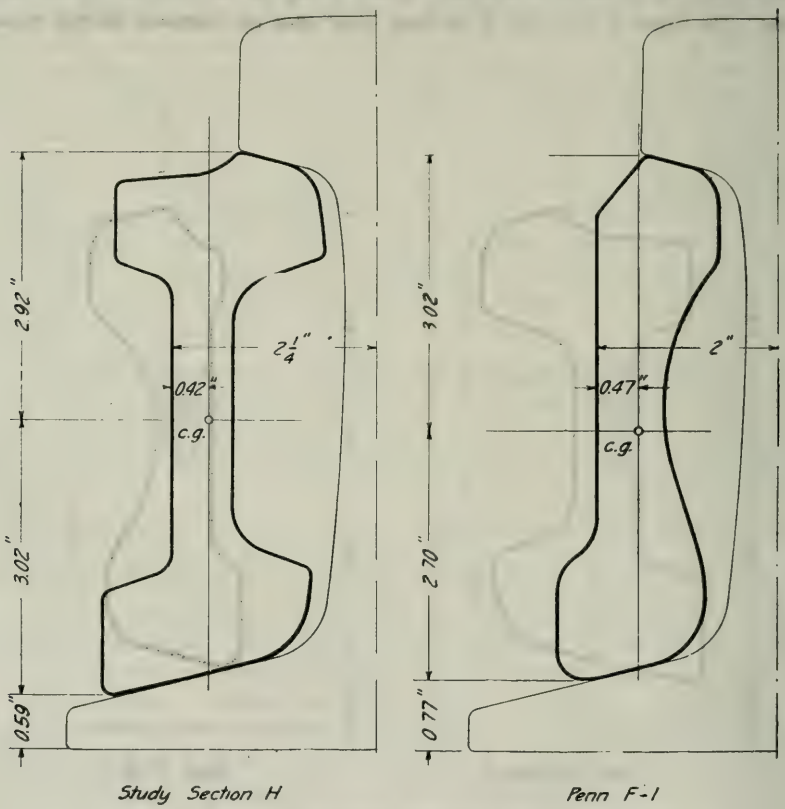


Fig. 87.—Sections of Joint Bars for 152-lb. P.S. Rail.

the tie support becomes troublesome or objectionable, especially at the full rail opposite the joint. The increased vertical stiffness of the rail support is due both to the greater number of ties per inch of rail and, what is more important, to the greater vertical stiffness of the ballast resistance because of the greater horizontal pressures developed in the ballast between more closely spaced ties for well-tamped track. This increased stiffness of the rail support at the joint ties has two effects (1) an increase in the vertical tie reactions (upward pressures) acting on the rail at and near its ends as compared with what is usually taken per inch of length of rail elsewhere with equally well tamped track, and (2) because of this change a reduction in the magnitude of the positive bend-

ing moment put into the joint bars by reason of the greater concentration of vertical reactions produced in the neighborhood of the rail-joint. With decreased spacing (the tamping remaining the same), then, the bending moment put into the joint bars is lessened and, besides, the deflection at the joint is decreased and the depression of the rail at this point is lessened. It is evident also that notwithstanding that the load on the ties per linear unit of length of track will be greater than elsewhere the added restraint in the ballast makes it capable of carrying the greater load if the depth of ballast is adequate. It is apparent that by proper spacing of joint ties the somewhat lesser stiffness of the rail-joint as compared with the full rail may be overcome and the vertical depression of the joint may be kept comparable to that of the full rail elsewhere. The foregoing statements assume that the rail-joint itself is of good design and fit and in proper condition—otherwise the moment developed in the joint bars may be relatively small and the joint will fail to perform its proper functions.

The extent of the decrease in the tie spacing that will give most satisfactory results can best be learned by experience. Two items need be taken into account in considering the problem of the best spacing—(a) the degree of effectiveness obtainable in tamping the track for the smaller spacings used and (b) on the other hand the possibility that the joint ties may be given so much decrease in spacing that hard supports in track will be produced at or opposite the rail-joints and thus be objectionable.

In Article 56 "Miscellaneous Features of Rail-Joints" of the Fifth Progress Report the effect of decreasing the spacing of ties at and near the joint was discussed at some length. It was concluded that the decrease in tie spacing should be arranged symmetrically with respect to the rail ends, two or four smaller spacings for a supported joint and three or even five smaller spacings for a suspended joint—even though rail creepage may later disturb the symmetry—making the outer spacings somewhat greater than those near the rail ends. The practice of the New York Central Railroad on the track tested was to make the two spacings at the supported joint 16½ in. instead of the 21 in. average for the other ties, and that of the Delaware, Lackawanna and Western Railroad was to space 19½ in. between the two ties at the suspended joint and 21 in. elsewhere. It would appear that a decrease in the spacing of the ties at and near the joint of 10 to 15 per cent below that used elsewhere may be expected to give satisfactory results with fairly stiff bars. If light bars are used or the bars are poorly fitting the spacing should be even less.

It should be accepted as a principle that so far as the number of tie spacings to be given a decrease in spacing and the amounts of these decreases are concerned, the length of the bars (whether short or long) and the type of the joint support (whether suspended or supported) will not enter into the problem, for it is the rail that is supported by the tie-plate and tie—the bar does not come in contact with the tie-plate—and for any ordinary form of joint bar the same change in stiffness of support will apply to different types. Features of slot spiking or of tie-plate fastening or other accessory matters may lead to preference for one way or another of arranging the joint ties, but generally even these differences may be arranged independently of whether the bars are short or long or whether the joint is suspended or supported. The notion that the joint is supported just in the length of the bar is not tenable. With such decreased spacing at the joint the track foreman will doubtless find that with substantial ballast of an adequate depth it will be unnecessary to tamp joint ties harder than other ties—a practice that seems to be not uncommon regardless of instructions to the contrary.

VIII. DISCUSSION OF TESTS OF TRACK

56. **The Analytical Consideration of Depressions, Stresses and Moments in Rail.**—In Chapter II of the First Progress Report "The Action of Track as an Elastic Structure"* a mathematical analysis was given and formulas developed for the depressions, upward pressures and bending moments in rail in track having a continuous elastic support for a single wheel load. For points away from the wheel load the distance from the wheel is then expressed in terms of x_1 (distance from wheel load to point of zero bending moment in the rail). The master diagram there given and reproduced here as Fig. 88 permits finding graphically the depressions, upward pressures and bending moments in the rail at any distance from the wheel load in terms of the values at the given wheel. To find the effect of a combination of wheel loads upon depression and pressure and bending moment in rail, as may occur with a given locomotive or a group of car wheels, the values found from the equations and diagrams derived for a single wheel load are utilized by means of the principle of superposition; that is, by considering that at any given point along the rail the combined effect of two or more wheel loads is the algebraic sum of the effects of individual wheel loads computed according to the distance from each of the wheels to the given point. The effect that each wheel load produces at any given point can be determined from the master diagram by the method outlined above, and the cumulative effect may then be found by adding algebraically the component magnitudes produced by each wheel load. Illustrations of component magnitudes and their cumulation may be seen in Fig. 89 and 90.

In this analysis of track as an elastic structure it is assumed that the rail is supported continuously on an elastic substructure and that this support has a constant modulus of stiffness; that is, that the depression of the track and the resulting upward pressure on the rail are directly proportional to each other. It is further assumed that the track construction is such that negative pressures may be developed under the same conditions of elasticity as are the positive pressures.

In track the ties do not form a continuous support and the support they give is not uniform in stiffness from tie to tie. Further, a variation in play between rail and rail support from tie to tie, especially in track having a very stiff rail support, will cause variations from point to point along the track. The weight of the rail and the downward pull of the substructure on the rail are not ordinarily effective in giving the full amount of negative pressure involved in the analysis to one side of the wheel loads, even though this pressure is relatively small. On the other hand, the use of a modulus of elasticity of rail support u determined for the usual conditions of the track with the regular tie spacing and an average stiffness of the track substructure gives values of depressions, pressures and moments at the important points on an average fairly close to the values observed in the tests. The analytical negative pressures are generally fully effective in playing their part in the cumulative effects of the several wheel loads for the whole length of the locomotive driver wheel base or the whole length of the two adjacent trucks of two coupled cars, and beyond the end wheels of a group the variations from the analytical values will not ordinarily cause large variations at points for which comparisons need be made. In this connection it may be well to note, however, that although the amount of negative pressure away from the wheel group is relatively small

* Proceedings, A.R.E.A., Vol. 19 (1918), p. 878. A resumé of the equations of the analysis, together with the master diagram, is included in the Fifth Progress Report, Vol. 31 (1930), p. 89.

its distance from a wheel is relatively large, so that its influence must have been applied in some way or the agreement of observed and calculated values at and between wheels would not be as close as has been found. An element in this action will be that if the rail is lifted from its support its whole weight will be available at once to give negative pressure, which though it may be much less than the analytical negative pressure will have a longer length and a greater moment arm than is implied in the analysis. Another discussion of the action of the weight of rail in producing negative pressure at points away from a wheel or group of wheels is given in Article 37 "Values of Modulus of Elasticity of Rail Support." The variation in play between rail and rail support may result in marked variations in stress in rail from tie to tie, which must be taken into account, but the average of observed stresses for spottings of wheels over a short stretch of track has been found to agree closely with the calculated value.

On the whole then it is evident that the analytical treatment has a useful value in discussing the stresses, moments and depressions of the rail and the pressure on the substructure, especially in making comparisons of the effect of differing spacing of groups of wheels and of changes in the stiffness of the rail and rail support. It may also be useful in discussing the effect of these variables on such matters as maintenance and deterioration of track. It is obvious, however, that a knowledge of the limitations of the accuracy of the method will lead to shunning great preciseness in its application and to avoiding generalization from minor details or from data on observations at a single spot when other factors (perhaps unknown ones) may have an important influence. It will be seen that a group of wheels rather than a single wheel should be used in making comparisons of moments, stresses, depressions and pressures for combinations of wheel loads.

For convenience of reference some of the principal equations found by the analysis for a single wheel load given in the First Progress Report are given:

$$p = -uy \qquad (6)$$

$$x_1 = \frac{\pi}{4}\sqrt[4]{\frac{4EI}{u}} \qquad (7)$$

$$M_0 = P\sqrt[4]{\frac{EI}{64u}} = .318Px_1 \qquad (8)$$

$$y_0 = -\frac{P}{\sqrt[4]{64EIu^3}} = -\frac{\pi}{8}\frac{P}{ux_1} \qquad (9)$$

$$p_0 = P\sqrt[4]{\frac{u}{64EI}} = -uy_0 \qquad (10)$$

It should be borne in mind that these equations apply directly to a single wheel load—a combination of loads requires the use of the principle of superposition as noted above.

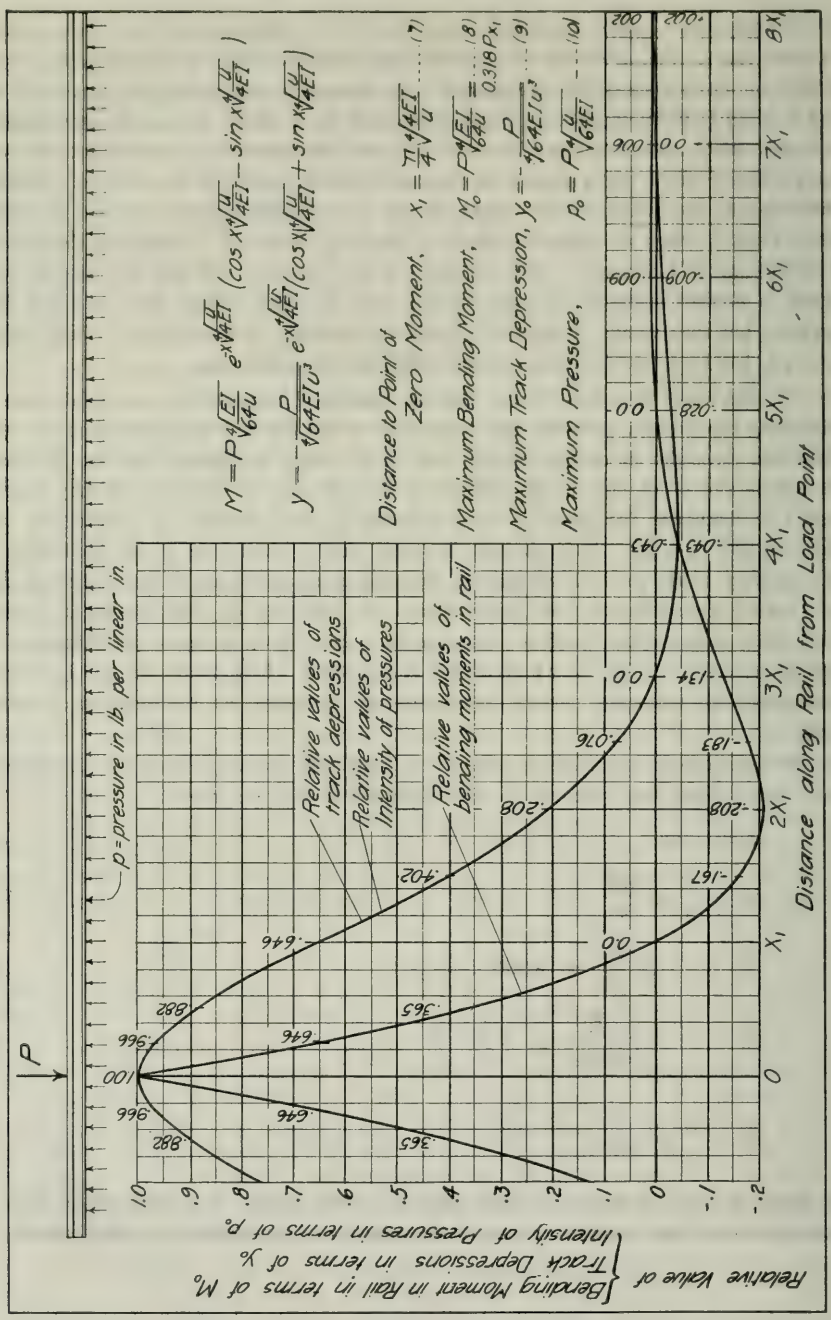


Fig. 88.—Master Diagram for (1) Moment Developed in Rail and (2) Intensity of Pressure against the Rail and Depression of the Rail — Single Wheel Load.

The nomenclature is as follows:

P = the weight of the single wheel load.
E = modulus of elasticity of steel.
I = moment of inertia of the rail section.
x_1 = distance from wheel to point of zero bending moment in rail.
y_0 = depression of rail at the wheel.
p = upward pressure against rail at any given point per unit of length of rail.
p_0 = upward pressure against rail at the wheel per unit of length of rail.
M_0 = bending moment in rail at the wheel.
u = modulus of elasticity of rail support.

The fundamental equations for the moments, depressions and pressures developed at any given point along the rail by a single wheel load are given in the First Progress Report. Instead of using these long and complicated expressions, the values at a given point may be obtained from the master diagram (Fig. 88) in terms of the values of the moment M_0, depression y_0, or pressure p_0 developed at the given wheel. The distance x_1 from the given wheel to the point of zero moment in the rail produced by that wheel load is first found by equation (7), and the distance x from the given wheel to the given point is expressed in terms of x_1. The diagram is then entered with this relative distance $\frac{x}{x_1}$ as the abscissa and the ratio or relative value of moment, depression or pressure given by the corresponding ordinate is taken off. The value at the wheel calculated for the single wheel load by equation (8), (9) or (10) is then multiplied by this ratio. The method of finding the moment, depression and pressure at any point along the rail due to a group of two or more wheels is illustrated in the following article. It should be noted that the modulus of elasticity of rail support u is the constant used in equation (6) in expressing for any point along the rail the relation between the upward pressure against the rail per unit of length of rail p and the depression of rail at the same point y. Thus, for u equal to 2,000 lb. per in. per in. and y equal to .20 in., the upward pressure on the rail p will be at the rate of 400 lb. per in. of length of rail.

In calculating the values given in this report the units inches and pounds are used.

57. **Relations of Rail Properties, Rail-Support Stiffness and Wheel Spacing to Rail Stress, Moment and Depression and to Tie Load and Other Matters That Influence the Durability and Upkeep of Track.**—The calculation and measurements of stresses and bending moments in rail and of pressures and depressions in the track have been found to give data by which certain characteristics of the action of track of different kinds and conditions may be compared and judged. Stresses in heavy rail may be well within a safe value and yet the greater stiffness and stability of the rail may serve a useful and economical purpose not measured by the needed strength. The magnitudes of the vertical movements of the rail upon the application of load (net depressions) give information of value in considering the qualities of track. In this discussion variations in play and stiffness from tie to tie will be neglected and only the net depression will be taken into account. In considering effects on the values of rail depressions, moments, and other elements, it is well to keep in mind that the magnitude of the moment of inertia of the rail section I is representative of the stiffness of the rail, and that the magnitude of the modulus of elasticity of rail support u is representative of the stiffness of the rail support, which includes the substructure of the track or part below the rail.

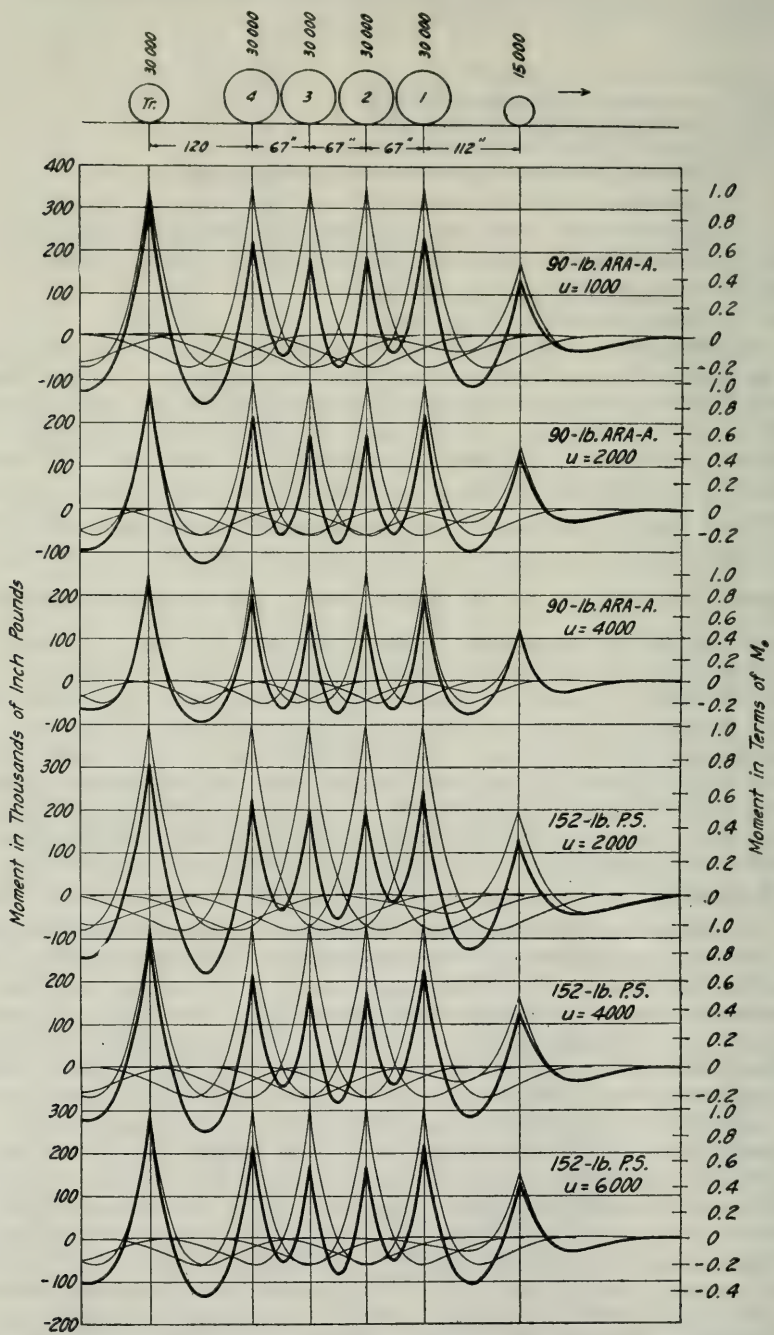


Fig. 89.—Magnitude and Distribution of Bending Moments in Rail for a Mikado Locomotive.

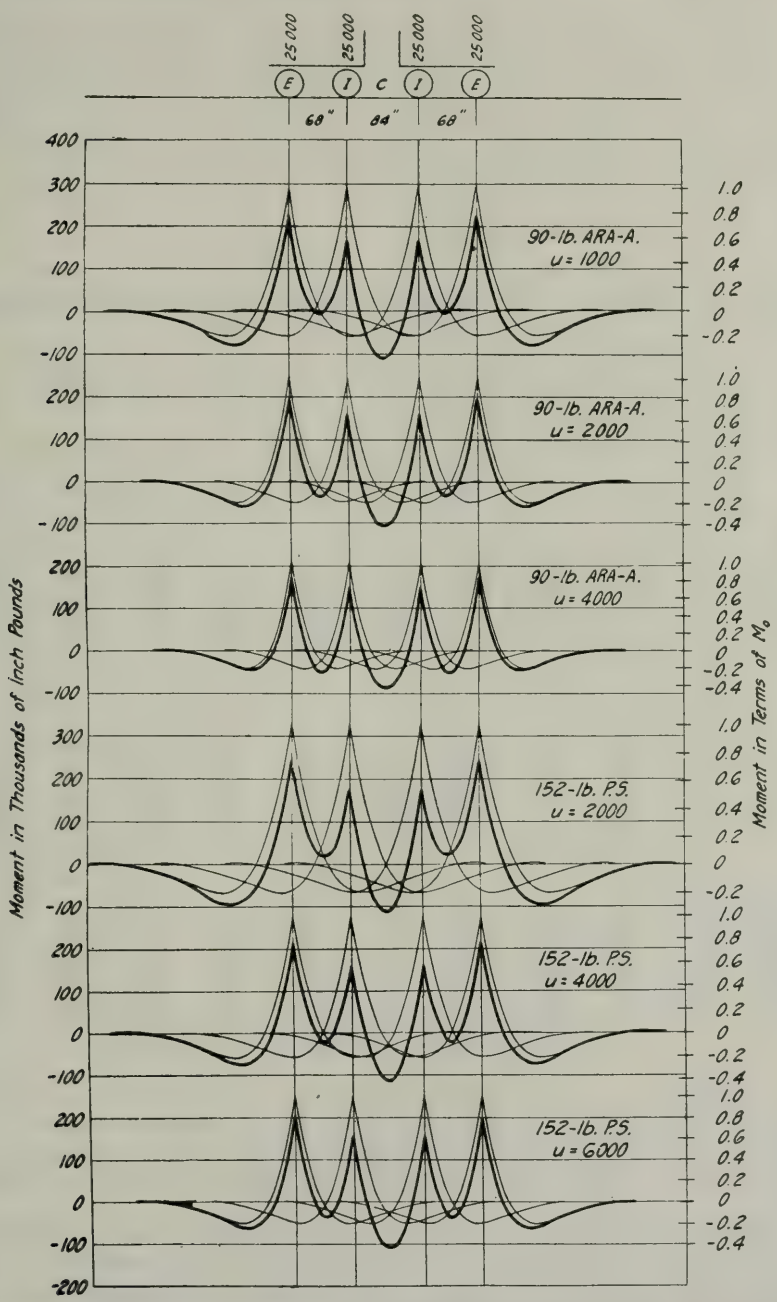


Fig. 90.—Magnitude and Distribution of Bending Moments in Rail for the Two Trucks of Two Coupled Coal Cars.

In Table 31 are given values of the distance from a single wheel load to the point of zero moment in rail, x_1, calculated from equation (7) for various rail sections and various values of the modulus of elasticity of rail support, u. By the analysis the distance from the single wheel load to the point of zero depression of rail is $3x_1$, and the pressure of the support on the rail would also be zero at this point. It will be seen from equation (7) that increasing both I and u results in no change in x_1 From Table 31 it will be noted that x_1 has its greatest value for low values of u and high values of I (a combination that is not likely to be found in track) and its least values for low values of

TABLE 31

Analytical Values of x_1, y_0, and M_0 for Various Rail Sections and Various Moduli of Elasticity of Rail Support u

x_1 is the distance (inches) from a single wheel load to the point of zero bending moment in rail. y_0 is the rail depression (inches) and M_0 the bending moment in rail (thousands of inch pounds) at a single wheel load of 30,000 lb.

u	85 ASCE	90 ARA-A	100 RE	110 RE	112 RE	127 NYC	130 PS	130 RE	131 RE	152 PS
	Values	of x_1								
1000	34.2	36.4	38.7	39.8	41.7	44.2	42.7	43.3	44.9	49.2
1500	30.9	32.9	35.0	35.9	37.6	39.9	38.5	39.1	40.6	44.6
2000	28.8	30.6	32.6	33.4	35.0	37.2	35.9	36.4	37.7	41.4
2500	27.2	29.0	30.8	31.7	33.1	35.2	33.9	34.4	35.7	39.2
3000	26.0	27.7	29.4	30.2	31.7	33.6	32.5	32.9	34.1	37.5
4000	24.2	25.8	27.5	28.1	29.5	31.2	30.2	30.6	31.7	34.8
5000	22.8	24.3	25.9	26.6	27.9	29.5	28.5	28.9	30.0	33.0
6000	21.9	23.3	24.7	25.4	26.6	28.2	27.3	27.7	28.7	31.5
	Values	of y_0								
1000	.344	.322	.304	.296	.283	.266	.275	.272	.262	.239
1500	.254	.238	.224	.218	.209	.196	.204	.201	.194	.176
2000	.205	.191	.181	.176	.168	.158	.164	.161	.156	.142
2500	.173	.162	.153	.148	.142	.134	.139	.136	.131	.120
3000	.151	.142	.134	.130	.124	.117	.121	.119	.115	.105
4000	.122	.114	.107	.104	.100	.094	.097	.096	.092	.084
5000	.103	.096	.091	.089	.085	.080	.083	.081	.078	.071
6000	.090	.084	.079	.077	.074	.070	.072	.071	.068	.062
	Values	of M_0								
1000	326	347	369	380	398	422	407	413	428	470
1500	295	314	334	342	359	381	367	373	388	426
2000	275	292	311	319	334	355	343	347	360	395
2500	260	277	294	302	316	336	324	328	341	374
3000	248	264	281	288	303	321	310	314	326	358
4000	231	246	263	268	282	298	288	292	303	332
5000	218	232	257	254	266	281	272	276	286	315
6000	209	222	236	242	254	269	261	264	274	301

I and high values of u (another unlikely combination). For rails from 90 lb. to 130 lb. and u from 2000 to 4000, x_1 ranges between 36 and 26 in. The value of x_1 for a given stiffness of rail and rail support is a useful quantity in the calculation of moments and depressions in rail and in finding the effect of other wheels by means of the master diagram.

In Table 31 are also given values of the rail depression at a single wheel load of 30,000 lb. calculated from equation (9). It will be noted the rail depressions vary considerably in passing from a light rail to a heavy rail and also in changing from a small value of u to a large value—differences which will not be found to hold true for a group

of closely spaced wheels. For a single wheel load other than 30,000 lb., the value of y_0 will be proportional to the ratio of the loads.

The value of the moment in rail at a single wheel load (M_0) is readily computed by the expression $.318Px_1$ of equation (8). Values of this moment for a single wheel load of 30,000 lb. are given in Table 31 for several rail sections and various values of u. For other single wheel loads the value of M_0 will be proportional to the ratio of the loads.

For a group of wheels having fairly close spacing the effect of the other wheels is to decrease the bending moment in rail at a given wheel. The effect of another wheel may be determined by entering the master diagram for moments with the distance from the given section to any wheel load expressed in terms of x_1 and multiplying M_0 by the proportional factor found. The effect of all the wheels is the algebraic sum of the individual effects. The resulting factor by which M_0 will be multiplied may range approximately from .50 to 1.00. For sections at points between wheels the operation is similar. To illustrate contrasts in the form of the moment distribution diagram for different stiffnesses of rail and rail support and different wheel spacings, the values and the distribution* of the moments in rail for a Mikado locomotive are plotted in Fig. 89. The light lines represent the values produced by the wheels singly, and the heavy lines the resultant value produced by all the wheels as found by taking the algebraic sum of the values shown by the light line. For simplicity the weights on the driving wheels and the trailer are here taken as equal; for unequal wheel loads the process would be the same. In the figure the moments are also expressed in terms of the moment for a single wheel load ($M_0 = .318Px_1$). It will be seen that the moment at the second and the third driving wheels is .51 to .67 times that for a single wheel load of the same weight and that at the fourth driving wheel .57 to .82, while the moment at the trailer is .64 to 1.01. In Fig. 90 are given the values and distribution of moment in rail produced by the two trucks of two coupled coal cars having a wheel load of 25,000 lb. Other wheel spacings, of course, will produce different magnitudes and distributions.

In Table 32 are given values of the moment in rail for the third and fourth driving wheels and the trailer of a Mikado type locomotive. While the moment at the fourth driving wheel ranges from .47 to .86 times that which would be developed with a single wheel, the moment at the trailer for the spacing used varies from .64 to 1.01 times that for a single wheel. In Table 31 it will be noted that for the single wheel the moment decreases as the stiffness of the rail support increases, the value of the moment with a modulus u of 6000 averaging about .64 times the moment with u of 1000 for each of the several rail sections, with changing decreases between the two limits of u. For the fourth driving wheel, however, the moment at the extremely high stiffness ($u = 6000$) is .86 times that for the very low stiffness ($u = 1000$) in the case of 90-lb. rail, and the cor-

* To illustrate the method of obtaining values at points away from a wheel, assume that $x_1 = 30$ in. and that the distance x from the given wheel to the section of rail under consideration is 68 in. Then $\frac{x}{30} = 2.27x_1$, and by the master diagram (Fig. 88) the moment at the section produced by the wheel load under consideration is —.20 times the moment M_0 at the wheel. Likewise the rail depression at the section produced by the given wheel is .13 times the depression y_0 at the wheel. The values produced by the wheels of a group are then found by taking the algebraic sum of the values at the given section produced by the several wheels.

responding ratio for 110-lb. rail is .90, for 130-lb. rail .94, and for 152-lb. rail .98. It is seen that the stiffer the rail section the less the effect of increased stiffness of rail support upon the decrease in moment developed in the rail at the fourth driving wheel. Similar comparisons may be made for the other driving wheels. For the trailer the corresponding ratio of the value of the moment at $u = 6000$ to that at $u = 1000$ ranges from .74 for 90-lb. rail to .94 for 152-lb. rail.

From Table 31 it is seen that the moment in rail developed at a single wheel would become greater as the rail section increases, the increase in moment being about one third for all values of u in going from the 90-lb. rail to 152-lb. rail. For the fourth driving wheel (see Table 32) relatively little difference is found at a given value of u between the moments developed in the several rails. For the trailer the differences increase from nothing at the low stiffness to a considerable difference at the highest stiffness. The stresses developed by the magnitudes of the moment, of course, are inversely proportional to the section modulus of the rail section.

TABLE 32

Moment in Rail at the Third and Fourth Driving Wheels and the Trailer of a Mikado Locomotive

Wheel load 30,000 lb. Wheel spacings as in Fig. 89. Moments are given in thousands of inch pounds. M_3 represents moment at the third driving wheel, M_4 that at the fourth driving wheel, and M_T that at the trailer.

u	90-lb. ARA—A			110-lb. R. E.			130-lb. R. E.			152-lb. P. S.		
	M_3	M_4	M_T	M_3	M_4	M_T	M_3	M_4	M_T	M_3	M_4	M_T
1000	184	222	302	194	221	308	215	223	310	235	221	301
1500	173	217	292	178	216	298	187	216	302	221	221	306
2000	172	216	280	176	217	291	184	222	302	201	225	308
2500	166	208	269	169	215	284	174	216	292	194	221	303
3000	166	208	261	170	213	277	173	217	292	186	218	308
4000	165	202	248	164	207	263	172	216	280	173	216	296
5000	160	197	234	165	203	254	166	213	270	173	217	293
6000	158	191	224	160	199	242	166	209	262	172	217	283

Except for very heavy rail on substructure with a low value of u, the moment at the third driving wheel given in Table 32 is smaller than that at the fourth driving wheel. This difference suggests the need of a proper division of the wheel loads and the allowed dynamic augment of unbalanced parts in the design and operation of motive power.

In Table 33 it is seen that the moment in rail at an end wheel of the group for the two trucks of two coupled coal cars (the end wheels giving the greater moment) for 152-lb. rail is about 1.25 times that for the 90-lb. rail through the whole range of values of u. For any rail the moment at an end wheel with u of 6000 is about .70 times that with u of 1000. The moments at the interior wheels have a smaller range of variation. Those at the coupler have more variation in some parts of the table.

For wheel spacings of locomotive and cars other than those given, the variations in moment and stresses due to changes in rail section and in stiffness of rail support will vary from those in the tables, but this discussion may serve as an illustration of changes that will be found.

The rail depression at a single wheel load (y_0) may be found from equation (9). It is proportional to the wheel load and depends upon both I and u, and it may be called inversely proportional to u and x_1. Values of y_0 are given in Table 31 for single wheel load of 30,000 lb. The depression for a group of wheels may be found by taking the proportional factor (positive or negative) from the master diagram of rail depression for the distance from the given section to each of the wheels of the group (expressed in terms of x_1) and multiplying the depression (y_0) for each wheel load by the corresponding factor and then summing algebraically the effects of the several wheel loads to obtain the cumulative depression. For illustrative purposes in Fig. 91 are plotted the rail depressions for a Mikado locomotive, and in Fig. 92 the rail depressions for two trucks of two coupled coal cars.

TABLE 33

Moment in Rail at the Wheels and at the Coupler of Two Trucks of Two Coupled Coal Cars

Wheel load 25,000 lb. Wheel spacing as in Fig. 90. Moments are given in thousands of inch pounds. M_E indicates moment at an end wheel of the group, M_I that at an interior wheel and M_C that at coupler.

	90-lb. ARA—A			110-lb. R. E.			130-lb. R. E.			152-lb. P. S.		
u	M_E	M_I	M_C	M_E	M_I	M_C	M_E	M_I	M_C	M_E	M_I	M_C
1000	226	165	—116	237	167	—120	255	182	—114	278	207	— 86
1500	206	157	—112	220	160	—117	237	171	—118	263	188	—114
2000	194	156	—107	210	160	—114	223	162	—116	243	174	—118
2500	184	152	— 99	199	154	—108	214	159	—115	237	168	—116
3000	181	152	— 97	192	154	—101	207	157	—113	229	167	—116
4000	172	150	— 90	181	150	— 94	195	156	—107	216	161	—116
5000	166	149	— 83	176	151	— 93	184	152	— 99	207	157	—110
6000	161	146	— 78	170	150	— 87	181	152	— 95	200	155	—110

The analysis shows that the rail depression for a group of closely spaced wheels varies only slightly with I of the rail section. In Table 34 are given the rail depressions at the main driving wheel (y_3) and the trailer (y_T) of a Mikado locomotive for several weights of rail and several stiffnesses of rail support and also half-way between the fourth driving wheel and the trailer (y_{4T}). It is seen that the depression at the main driving wheel does not vary far from being inversely proportional to u regardless of the weight of rail. The values for the other drivers are similarly nearly inversely proportional to u. The weight on the drivers is evidently supported by about the same length of track, and the average depression of rail along this length does not vary greatly regardless of rail stiff-

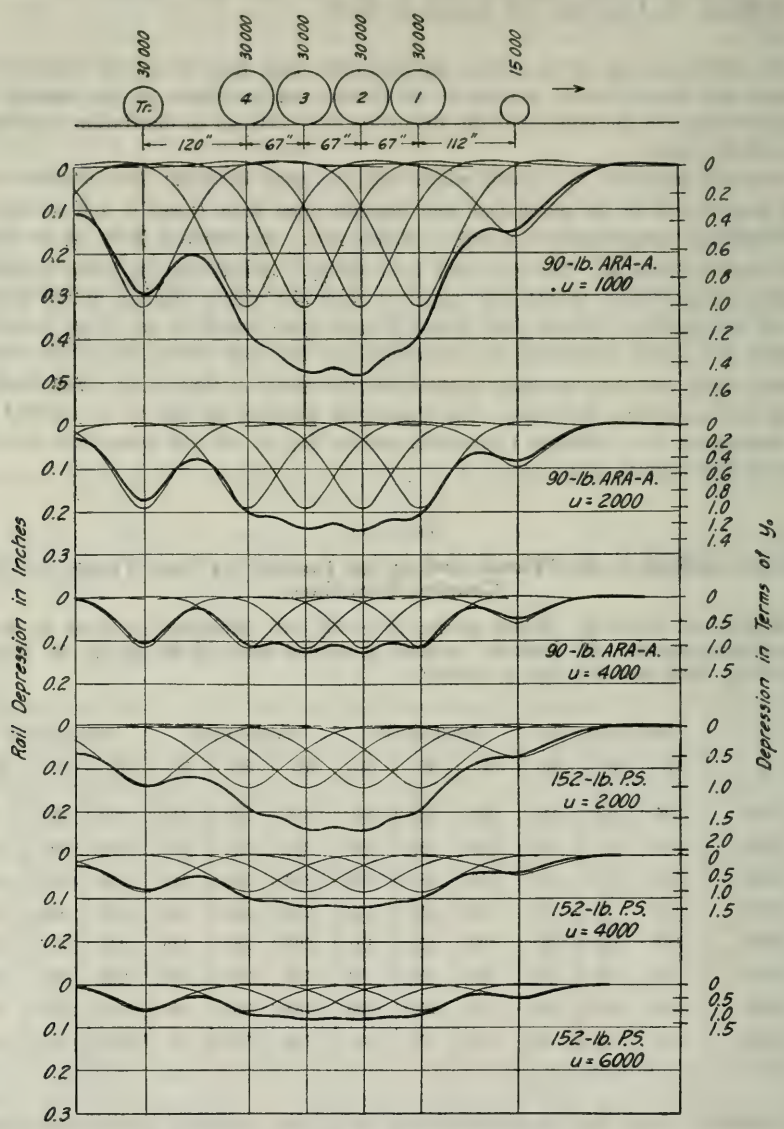


Fig. 91.—Rail Depression for a Mikado Locomotive.

ness, and this average depression is nearly inversely proportional to u. For the wheels of the two trucks of two coupled coal cars given in Table 35 similar relations for the average depression are found. For a given value of u the maximum rail depression at a wheel is little affected by the rail section, though it is slightly greater for the lighter rails. For the 90-lb. rail the maximum rail depression at a wheel is 15 or 20 per cent greater for u of 6000 than that obtained from the value at u of 1000 by the assumption

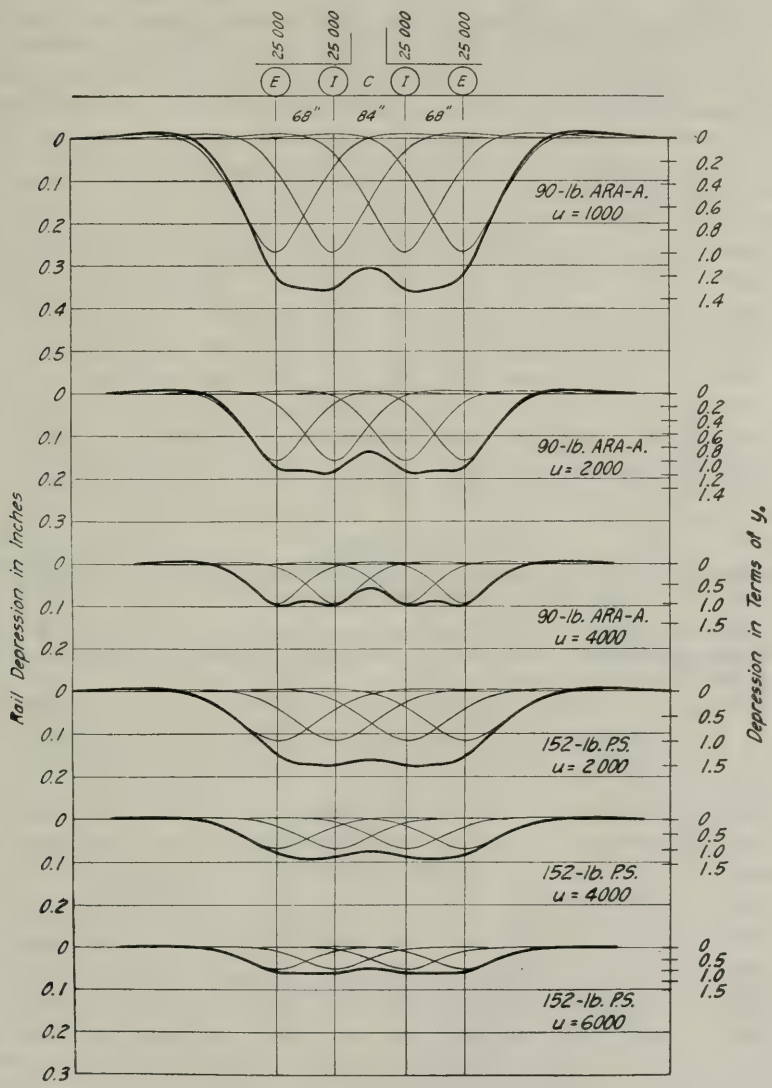


Fig. 92.—Rail Depression for the Two Trucks of Two Coupled Coal Cars.

that the rail depression is inversely proportional to u. For the other rails the values do not differ much from inverse proportionality. Somewhat similar conclusions may be drawn concerning other types of heavy locomotives and freight cars.

Since the intensity of rail pressure is proportional to the rail depression and to the modulus u (equation (10)) and since as has just been shown for the main driver the product of rail depression and modulus u is nearly constant, it follows that the upward

TABLE 34

Depression of Rail at Main Driving Wheel and Trailer and Half-Way between Fourth Driving Wheel and Trailer of a Mikado Locomotive

Wheel load 30,000 lb. Wheel spacing as in Fig. 91. Rail depression in inches. y_3 indicates depression at main driver, y_T depression at trailer, and y_{4T} depression half-way between fourth driver and trailer.

u	90-lb. ARA—A			110-lb. R. E.			130-lb. R. E.			152-lb. P. S.		
	y_3	y_T	y_{4T}	y_3	y_T	y_{4T}	y_3	y_T	y_{4T}	y_3	y_T	y_{4T}
1000	.47	.30	.20	.47	.28	.22	.46	.26	.24	.46	.25	.26
1500	.32	.22	.12	.32	.20	.13	.31	.19	.15	.31	.17	.16
2000	.24	.18	.08	.24	.16	.09	.23	.15	.10	.23	.13	.12
2500	.19	.15	.06	.19	.14	.07	.19	.12	.07	.19	.11	.09
3000	.17	.13	.04	.16	.12	.05	.16	.11	.06	.16	.10	.07
4000	.12	.11	.02	.12	.10	.03	.12	.09	.04	.12	.08	.05
5000	.10	.09	.01	.10	.08	.02	.10	.08	.03	.10	.06	.04
6000	.08	.08	.01	.08	.07	.01	.08	.07	.02	.08	.06	.03

TABLE 35

Depression of Rail at the Wheels and at the Coupler of Two Trucks of Two Coupled Coal Cars

Wheel load 25,000 lb. Wheel spacing as in Fig. 92. Rail depression in inches. y_E indicates depression at an end wheel of the group, y_I depression at an interior wheel, and y_C depression at the coupler.

u	90-lb. ARA—A			110-lb. R. E.			130-lb. R. E.			152-lb. P. S.		
	y_E	y_I	y_C	y_E	y_I	y_C	y_E	y_I	y_C	y_E	y_I	y_C
1000	.32	.36	.31	.31	.36	.32	.30	.35	.33	.28	.35	.34
1500	.23	.24	.19	.22	.24	.20	.21	.24	.21	.20	.24	.22
2000	.18	.18	.13	.17	.18	.14	.16	.18	.15	.15	.18	.16
2500	.15	.15	.10	.14	.14	.11	.13	.14	.12	.12	.14	.13
3000	.13	.13	.08	.12	.12	.09	.11	.12	.09	.11	.12	.10
4000	.10	.10	.06	.09	.09	.06	.09	.09	.07	.08	.09	.07
5000	.08	.08	.04	.08	.08	.05	.07	.07	.05	.07	.07	.06
6000	.07	.07	.03	.07	.06	.04	.06	.06	.04	.06	.06	.05

pressure at the main driver is nearly the same for any rail section and any rail support stiffness included in Table 34. For other driving wheels the relation existing between intensity of pressure and I and u does not vary greatly from uniformity. In other words, the pressure of rail on individual ties at or near the main driver (and to nearly the same extent at the other drivers) differs little for these several weights of rail and for the range of values of u. It will be noted from the values of Table 35 that the maximum tie pressure at a wheel of the two trucks of the two coupled coal cars will not differ much for the different rails and different values of u except that for the 90-lb. rail

the maximum tie pressure will increase from u of 1000 to u of 6000 by a total of 15 or 20 per cent. Although the rail depression at a wheel may be greater or less than at points between wheels, depending upon I and u and the wheel spacing, it may be expected that the average tie pressure within a group of closely spaced wheels, whether of a locomotive or coupled cars, will not differ greatly through the range of rail weights and of rail support stiffnesses. Evidently the magnitude of the wheel spacing exerts the greatest influence on the tie pressures within the more usual wheel spacings used in such groups of wheels. For longer wheel spacings the variations will be greater and for spacings more than, say, 7 feet the conclusions given above may not apply and a special study should be made. It should be understood, of course, that this discussion assumes relatively small variability in play between rail and tie; for track having much variability in this respect the variations in tie pressure are quite different, as will be seen in Article 59 "Variability in Track and Its Effect".

Assuming then that the average tie pressure throughout the length of a group of wheels, due to given wheel loads, is approximately independent of the rail section and likewise independent of the stiffness of rail support, attention may be directed to the vertical movement of the rail support when this group of wheels moves along the track. From Table 35, it is seen that the maximum downward movement of the rail at one of the four wheels of the trucks of two coupled cars as the wheel loads are applied is about .25 in. for u of 1500 and .10 in. for u of 4000. This means for track having little play between rail and rail support that the rail and the top of tie move downward for the less stiff support say 2.5 times as much as they do for the stiffer support. The downward movement within the ballast under the tie will have a somewhat similar ratio of movements. All of the movements are followed by a corresponding rise when the wheels have moved on.

This up-and-down movement under applied and released tie pressure every time a pair of coupled trucks moves by with approximately the same magnitude of tie pressure whether the movement by .25 in. or .10 in., is a form of repetitive loading which, of course, has its effect on the stability of the substructure and on the duration of continuance of good line and surface. It is evident that the effect of repetition will vary in some way with the magnitude of the vertical movement. Although quantitative relations are not known, it is to be expected that the less stiff track will be put out of form with the passage of much less traffic, especially if the track is variable in condition from from point to point and tie to tie. Such a finding is only a restatement of common knowledge that a substantial track substructure having deep and consolidated ballast on a solid roadbed will carry a much greater amount of traffic without maintenance work than will a less stiff substructure.

The data on rail depression were obtained by the application of load statically. Little information is available on the effect of speed on rail depression, and it would be difficult and time-consuming to obtain definite and adequate data on it. Variations in the transfer of load from wheel to wheel and from rail to rail occur with moving loads, especially at the higher speeds, and, besides, there probably is an increase of the load effect with an increase in speed which may be treated as an increase in the load. For the purpose, this increase in load may be thought of as similar to the increase in stress in rail with increase in speed which has been obtained and is recorded in previous progress reports. For rough track the effects of speed will be even greater on tie pressures than on rail stresses.

58. **Method of Determining the Modulus of Elasticity of Rail Support u.** —The following article has been prepared in answer to requests for a definite description

of the method used in making determinations of the value of the modulus of elasticity of the rail support by field tests. It will be understood that the principal purpose of u is for the use in calculating moments and stresses in rail and rail depressions and the corresponding pressures of the rail on the ties. These calculations would be applied to the effect of wheel load and wheel spacing of groups of wheels and to the effect of the dynamic augment and other loads on the rail and substructure of track. The magnitude of u is representative of the stiffness of the substructure (the part below the rail), which acts as the rail support.

In considering methods of determination it should be kept in mind that the resistance of the substructure to pressure from the rail varies from tie to tie, and especially that the amount of the play between rail and tie bed in passing from the unloaded position to the fully loaded position varies considerably. The determination then must consider the net vertical movement of the rail—that is, the part of the movement that is resisted by tie pressure. A satisfactory method will take into account the average resistance of the ties and ballast in resisting the vertical movement of the load. The greater the variation in this play, the less accurately the calculated values will fit the observed values. Since track will have general variation in depressions and stresses from place to place it will be necessary to make tests at several locations. The effort should be made to test average or usual conditions of the track, though of course the effect of special conditions of track may well be tested separately.

The variations in play and the consequent uncertainty in the load carried by the ties toward the ends of the positive rail depression make it difficult to determine the magnitude and extent of the upward or negative pressure. Because of this and because the amount and distribution of negative pressure outside the wheel base of a group of wheels is rather indeterminate, and because the weight of the rail itself may act to its full amount at a greater distance from the group of wheels than is implied by the analysis, it is best to disregard the upward movement and the corresponding negative effect in the field test for the determination of u. For points between closely grouped wheels the effect of the negative pressure assumed in the analysis within the length of the group will be fully taken care of by the cumulative effect of positive and negative pressures contributed by two or more wheels. The effect of the neglect of the negative pressures outside of the group upon the value of u may be estimated as about 3 per cent in tests with a four-wheel freight truck; it will be still less for the two trucks of two coupled cars and for the driving wheels of a locomotive. The depressions calculated from u determined in this way agree on an average very closely with the net depressions for the length of the group of wheels observed on the same stretch of track. Similarly the observed stresses in rail and the stresses in rail calculated with the observed value of u agree closely at the wheels. It should be added that the negative pressure away from the group of wheels is itself an important element in the make-up of the magnitude of the moment at a wheel, but the magnitude and distribution of the weight of the rail away from the group of wheels itself apparently has about the same influence as would the negative pressure assumed in the analysis.

In general, then, the assumption may be made that the weight of the closely spaced group of wheels is carried by the ties that are found to have a positive net depression and that the load carried by a tie is proportional to its net downward depression. Since the assumption of the analysis implies a continuous rail support, the track conditions may be approximated by considering that a tie load is distributed over a total distance equal to one tie spacing. For uniform tie spacing the value of the modulus of elasticity of rail support u for one rail may then be found by dividing the sum of the wheel loads

on one rail by the product of the average spacing of the ties center to center and the summation of the net downward rail depression at each tie considered.

To eliminate most of the effect of irregularities of play and obtain net rail depressions, both a light load and a heavy load should be used in the tests. The weight of the light load should be sufficient to overcome most of the play so that all ties within a given limit of length (say, between the third ties beyond the end wheels of the group) may be expected to carry load. The heavy wheel load may well be greater than the maximum wheel load ordinarily carried by a car, in order that the range between light load and heavy load will be as great as possible. Although the two trucks of two coupled freight cars would be a desirable form of loading, the use of one truck of a freight car is simpler and has been found satisfactory. For the light load a wheel load of 6000 or 7000 lb. is suitable. For the heavy load a wheel load of 30,000 lb. at one end of the car is desirable, though one of 26,000 lb. may be used if a heavier load is not available. The two cars should have the same wheel spacing and be of the same type and should be in such condition that the division of load among the four wheels of the truck will be equal.

In making a test at a given location the rear wheel of the car (either the light load or the heavy load) is carefully spotted at a given point of the rail.

Fig. 93.—View of Special Level Rod.

In making a test levels are taken on the base of rail at each successive tie with an engineer's level for the rail unloaded, loaded with the light load, loaded with the heavy load, and again unloaded. A special level rod (see Fig. 93) 6 in. long graduated on the celluloid face to one-hundredth inch has been found very satisfactory for this use. The pointed end of this level rod is placed in a punch mark in the base of the rail made at every desired point. A spherical level bubble at the top of the level rod permits holding the level rod in a truly vertical position. In taking levels the rod is read directly to the nearest hundredth inch or to the nearest half-hundredth. The engineer's level may be set opposite the middle of the truck and about 10 feet from the rail and, of course, must be set low. As the measurement for each point on the rail is found from the difference between readings for loaded and unloaded rail (without calculating elevations), refinements in adjustment of the instrument though desirable are not essential, but the level bubble of the instrument must be held in exact position when reading the rod at every point for every set of readings. Check readings should be taken on a bench-mark close by—better on a bench to the left and one to the right. To ensure accuracy it is well to keep a second man at the instrument watching the level bubble. As extreme accuracy is necessary, the sets of level readings for unloaded and loaded rail must be taken in a continuous operation—the removal of the test car before the completion of the set of readings will result in uncertain data and probably slightly changed conditions in the rail and the load, which would render the work of doubtful value. Trains passing on a nearby track at moderate speed are not likely to affect the levels that may be taken afterwards.

In addition to the rail depression tests, pull-up and push-down tests are needed over the length of rail for which the rail depression test is made. In the push-down test a bar is placed under the rail head and over a fulcrum block resting on the tie at the gage side of the rail, and downward pressure is exerted by a man at the further end of the bar, the spikes or other fastening having been loosened somewhat if necessary to clear the rail base. The pull-up test is made by inserting the bar through ballast under the end of the tie, using a short block as a fulcrum, and then applying pressure at the further end of the bar. Just enough effort is made to bring the rail and tie-plate and tie into contact and not enough to lift the rail. Using methods similar to those of the rail depression tests, level readings are taken on a tack in the top of each tie close to the tie-plate (1) for the tie in the original condition, (2) with the push-down force applied, and (3) with the pull-up force applied; this whole operation takes about one minute for each tie. The differences in the readings at original condition of tie and at push-down and pull-up positions give the magnitude of the play between tie and ballast bed and between rail and tie, respectively. The sum of the two is the play between rail and tie bed. As the readings are taken at a point on the tie away from the rail, the results do not give the exact movement of the tie with respect to the rail, but the values are sufficiently accurate for the purpose intended.

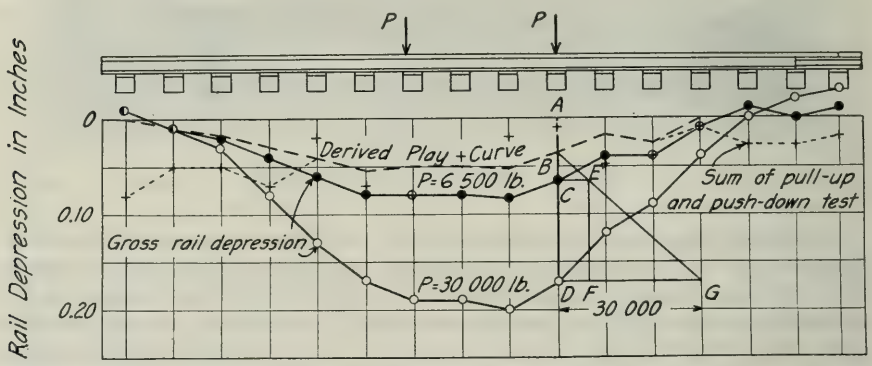


Fig. 94.—Example of Gross Rail Depression and Net Rail Depression Made by Two Wheels of a Coal Car Truck.

The data of the tests may be plotted as in Fig. 94. The gross rail depression at a given tie for a given load is the difference between the rod reading with unloaded rail and loaded rail. In the figure the plotted gross rail depressions for the heavy load have been connected by lines, as are also the gross rail depressions for the light load. The ordinates of the derived play curve (*AB*, for an example) were calculated on the assumption that the light load (6500 lb., *CE*) has brought the rail and tie to a firm bearing at each tie and that the further depression (*CD*) made by the heavy load (*DG*, 30,000 lb.) is proportional to the added load (*FG*, 23,500 lb.). The calculated net rail depression for the heavy load (*BD*) leaves a vertical distance (*AB*), which is termed the derived play and the line connecting their ordinates the derived play curve. The rail net depression at any tie is represented by the distance from the derived play curve to the curve of gross rail depression.

The sum of the pull-up and push-down measurements for each tie are also plotted in Fig. 94 by + marks. It will be seen that throughout the middle portion of the length some of the plotted points are above the derived play curve and some are below it. If a tie within this length is found to carry no load when the light wheel load is applied, it is obvious that adjoining ties carry more than the share indicated by the net rail depression for that load; it follows then that by the method outlined in the preceding paragraph the resulting net rail depressions give values proportional to the average tie loads.

It is evident that the ties at the two ends of the length of the diagram having pull-up and push-down points below the gross rail depression points for the heavy wheel load do not carry load and the rail depression at these ties should be omitted in the calculation of u. Generally, in the reduction of data, two or three ties outside the wheel loads were included and their depression measured from the derived play curve, even when the pull-up and push-down point is below the derived play curve. Outside of these three ties the vertical distance was measured from the points of the pull-up and push-down test.

The sum of the rail net depression ordinates at each tie obtained as just described is then found; for the data given in Fig. 94, this sum is .97 in. The load on the rail, 60,000 lb., is then divided by the product of this sum of the net depressions and the average tie spacing, 21.3 in. The quotient is the modulus of elasticity of rail support u, which in the case used is 2900 pounds per inch per inch. It may be added that a somewhat simpler procedure uses the differences between the rail depression for the light load and for the heavy load (CD), with the modifications at the ends obtained from pull-up and push-down data as in the other procedure, and takes the difference between the heavy load and the light for the effective load. For example, the summation of the rail depressions for this procedure is .77 in. and the effective load 47,000 lb.

For further details of the method and its applications reference may be made to Chapter V "Track Depressions and Rail Stresses in Tests on the Chesapeake and Ohio Railway" and Chapter VI "Tests of GEO Track on the Missouri Pacific Railroad". As a word of caution it may be well to repeat the statement that because of variability of track the determination of u should be made at three or more stretches of the track.

59. **Variability in Track and Its Effects.**—In Article 57 "Uniformity and Variability in Track"* of the Fifth Progress Report a short discussion was given of variations which had been found in track and the accompanying disadvantages. The tests described in this report give more detailed information on the nature and magnitude of such variations and show rather marked contrasts resulting from differences in conditions on the test stretches of two railroads. Both tracks would be called high grade track, well ballasted, and would be considered to be in well maintained condition. Certain features of the two tracks were different. In one certain conditions promoted uniformity of action in the structure; in the other greater variability was found.

In Chapter V "Track Depression and Rail Stresses in Tests on the Chesapeake and Ohio Railway", the test stretches of track on the Chesapeake and Ohio are described as substantial track—new 130-lb. rail, large tie-plates, good oak ties, deep consolidated ballast, and thoroughly compacted roadbed. Although not specially different from ordinary practice the tie spacing and tie width were not very regular, the tie-plate bearings were uneven and partially out of the plane of the rail base, and the play between rail

* Proceedings, A.R.E.A., Vol. 31 (1930), p. 325.

and tie-plate and tie varied from tie to tie considerably. The traffic was very heavy, but the track had been tamped four weeks before the tests were made. Altogther the track would usually be considered as in ordinarily good or excellent surface and alignment.

In the tests of stress in the two edges of the base of rail made at every other tie, marked variation in both the edge stresses and the mean stress in base of rail at the four locations used was found (see Fig. 70 and 71). In Fig. 95, the stresses at the two edges and the mean stress in base of rail, all given in terms of the average stress along the track as unity, have been plotted for both rails at two of the four test locations, the

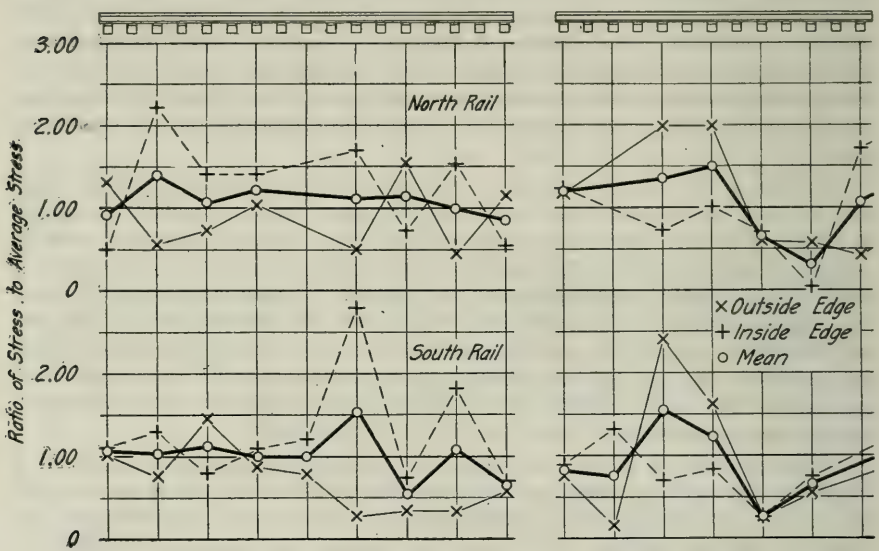


Fig. 95.—Examples of Ratios of Stress at the Two Edges and the Mean Stress in Base of Rail to the Average Mean Stress along the Track.

ordinates of the points along the light full line representing the stress at the outer edge of the rail and those along the dotted line the stress at the inner edge, with the points along the heavy line representing the mean stress in base of rail. The greater stress is sometimes at one edge and sometimes at the other, quickly changing from one side to the other and ranging from nothing at one edge of the base of rail to double the average stress at the other edge and in one case even to three times the average stress. At one place in the tests a compressive stress was developed at one edge having a value of more than 50 per cent of the average mean tensile stress along the track. At one place the stress at one edge of the base of rail was 3000 lb. per sq. in. and at the other edge 28,800 lb. per sq. in., making a mean stress in base of rail of 15,900 lb. per sq. in. as compared with an average mean stress of 9700 lb. per sq. in. at all the places along the same rail. As lateral forces of considerable magnitude will doubtless be developed from the lateral swinging and side thrust of locomotives and cars at high speeds, it is to be expected that the large stress at one edge of the base of rail would be greatly increased under the loads of traffic.

These differences in stress at the two edges of the base of rail and the changes in position of maximum stress indicate a constantly changing lateral bending, sometimes one way and sometimes the other (frequently resulting in unduly high stress at one edge of the rail), and also a marked twisting in the rail. The amount and direction of the lateral bending of the rail from point to point may be seen from the lateral moments plotted in Fig. 73. It should be noted that the measurements were made by moving the load from point to point along the track and always measuring stress in rail directly under the rear wheel, and the movement of the load was such that the pressure of the wheel on the rail was essentially alike in all cases and the wheels were at relatively the same place on the top of the rail, thus applying almost identical vertical and lateral loads at every spot. In considering these variations in stress, it is not a question of the ability of the rail to take these twisting and lateral bending stresses that is of the greatest importance but rather the fact that the tests show extreme variability in the action of the track and a very marked change in the position and direction of the forces applied to the rail by the supports at the ties along the track. The question arises as to what are the causes of the variability and what are the effects on the track (the ties and tie-plates and ballast bed as well as the rail) and on the matter of maintenance.

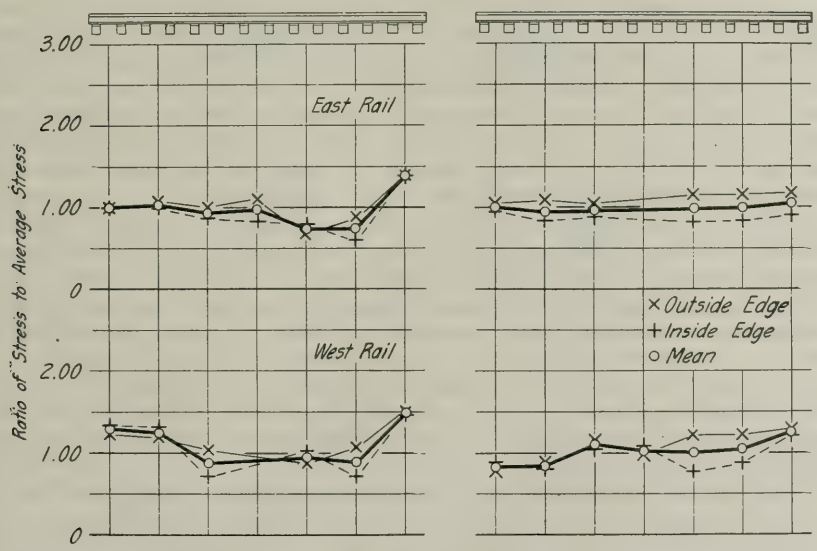


Fig. 96.—Examples of Ratios of Stress at the Two Edges and the Mean Stress in Base of Rail to the Average Mean Stress along the Track.

The heavy line of Fig. 95, drawn through the points of mean stress in base of rail, may be considered as representative of the vertical bending moment developed in the rail from point to point. These mean stresses vary greatly from point to point along the track, being as much as 1.6 times the average stress along the track and at another place not far away only three-tenths of the average stress. That is, the mean stress in base of rail as measured on these stretches of track varied from .3 times the average stress along the track to 1.6 times the average stress, and this with the same load applied

in the same way. Doubtless wider extremes than these may frequently be found in track.

In Chapter VI "Tests of GEO Track on the Missouri Pacific Railroad", tests are reported on track which gave much greater uniformity in stresses in rail and in other ways. This GEO track has stiff tie-plates with the rail base fitting in closely between the two shoulders of the tie-plate and held to it tightly by bolts. A thin compressed wooden shim lies between the rail and the tie-plate. The ties were preadzed and prebored in such way as to make the base bearing of the two tie-plates on a tie fit the tie surface accurately and lie in the same plane, so that the rails will bear fully and uniformly on every tie-plate and that both rails will have the same cant. Likewise the rails were thus brought into proper gage when the screw spikes were applied and the wood under the tie-plate compressed somewhat by the spike tension. As stated in more detail in Chapter VI the roadbed was old and solid, the ballast (in some locations hard limestone and in others flint gravel) was of good depth and well distributed and consolidated, the ties were sound and straight and uniform in size and spacing, and the track in general excellent condition, though no maintenance had been given in the year it had been in service. The road was used principally for passenger service and the freight traffic had been light.

The measurement of stresses in base of rail at points between ties made on both rails at every other tie space for four test locations showed excellent uniformity and relatively little variation at the two edges of the base of rail for the four locations at which stresses were observed (see Table 28 and Fig. 78 and 79). In Fig. 96 are given for two locations the stresses in the two rails expressed in terms of the average stress along the track as unity. The variation of the stress at an edge of rail from the mean stress in the base for a given point is relatively very small and the freedom from lateral bending of rail correspondingly small (see Fig. 81 for plotted values of the lateral bending moments). The variation in mean stress and moment in rail from point to point along the track was also relatively small. Except for six places at which the two ties adjacent to the wheel had little play and the rail support was very stiff and where for two or three ties each way there was relatively more play, thus developing relatively small stresses and moments at the wheel, the variations in stress were small. Omitting the six low values, five places gave values 25 to 36 per cent greater than the average and two places 26 and 25 per cent less; the other 23 places gave an average variation from the average value of the mean stress of 13 per cent. For the fourth test location the variation was still less. Considering the natural variability of the track structure these results show exceptional uniformity of track.

The source of the variability in rail stresses along a track is evidently the variability in the rail support given by the substructure—in its stiffness in resisting pressure, in its position with respect to the rail, in the variation in vertical play between rail and ballast bed under the tie when load is applied which causes marked differences in the load carried by ties in the same group. The pull-up and push-down tests on the Chesapeake and Ohio Railway indicate great variations in load-taking characteristics at nearby ties because of the play between rail and tie and between tie and ballast bed (see Fig. 64, 65 and 66). The variation in rail depression as a wheel is moved from point to point along the track is quite marked, even though the rail acts to distribute the load over several ties (see Fig. 62 and 63). The examples of the division of load among a group of ties shown in Fig. 67 illustrates the great variability in load-carrying opportunity given to ties in track by moderate wheel loads—values ranging from zero to 2.5 times the average load. This variability is caused by what has been termed the varying play between the rail and its support. And these variations are found in track hav-

ing substantial stiff substructure considered to be in excellent condition. With such variations in tie pressures both ties and ballast receive abnormal loads.

The variations in play between rail and tie bed found in the tests on the Missouri Pacific Railroad are smaller, even on the very stiff substructure, and the rail is correspondingly freer from marked changes in stress from point to point. However, the variation in vertical play between rail and ballast bed was sufficient to have caused considerable variation in the loads from tie to tie.

A principal source of the variation in stresses at the two edges of the base of rail from point to point as referred to above lies in the unevenness of the bearing of the rail on the tie-plate or of the tie-plate on the tie and even of the tie on its ballast bed. The unevenness may seem small but with the stiffness of the rail the varying position of the resultant of the tie reaction on the rail will result in lateral bending and twisting effects. Instead of the bearing pressure being uniform and the resultant of this pressure being at the center of rail base and width of tie, as indicated in the upper left corner of Fig. 97, the position of the resultant may be near one edge of the face of the tie (lower left corner of the figure), or the centroid of pressure may be at one side of the rail or the

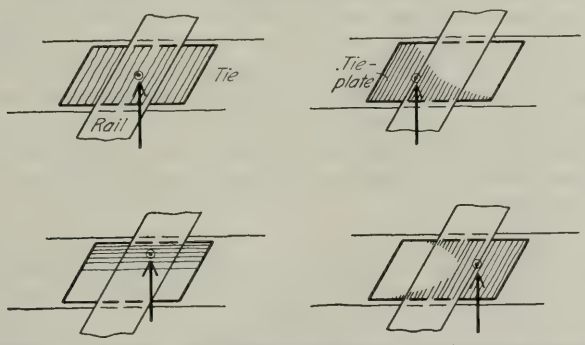


Fig. 97.—Diagram Indicating Variations in Position of the Resultant of the Tie Reaction on the Rail.

other (right side of the figure), possibly with adjacent ties having conditions of bearings of opposite kinds thus concentrating vertical pressures first at one edge and then at the other edge of the rail. A gage the thickness of a piece of paper or even the blade of a shovel may be inserted at some spot under the rail or under the tie-plate and not elsewhere, so that with the stiff rail and a stiffly bedded tie the pressure will be concentrated near one edge of the rail. With the bending and twisting effect applied to the rail goes a corresponding eccentricity of pressure on tie and ballast which concentrates the load and otherwise produces undesirable distribution of pressures and contributes to an increase in maintenance costs.

The freedom from lateral bending and twisting in the rail on the track tested on the Missouri Pacific Railroad and the correspondingly even bearing of rail on tie may be accounted for principally by the method of machine adzing and boring the ties in such way that the plane of the base of both rails is made to coincide with the bearing plane of the tie-plate and the latter has an even and uniform bearing on the tie and is permanently held down firmly against the tie. A similar uniformity of action was observed in track having the tie-plates applied in a similar way on the Delaware, Lackawanna and Western Railroad in tests made in 1925 and 1926.

The variability found in the test stretches of the Chesapeake and Ohio Railway is not peculiar to this track—observations made on many railroads indicate that the same conditions exist quite generally—probably on most railroads. The tests call attention to the unfavorable effects of the variable conditions described.

An item not connected with the foregoing discussion may well be mentioned. Although the inclination of the tie-plates themselves was 1 in 28, observations made at 63 points along the stretch of track tested on the Chesapeake and Ohio Railway showed that the south rail had an average measured cant of 1 in 16 and the north rail 1 in 27, the cant for each rail being fairly uniform throughout. This difference in cant evidently caused the flange of the south wheels in moving along the track to hold closely to its rail (the one having the larger cant) and also gave direction to the lateral bending in the two rails. The two rails were on the same level.

60. **Influence of Strength and Stiffness of Rail and Stiffness and Uniformity of Substructure on the Quality and Stability of Track.**—The purpose of the tests made by the Committee in the nineteen years of its work has been not alone to determine how large are the stresses in rail and its depression in track; a main purpose has been to obtain data from which a study of track conditions and track properties may be made, to find the characteristics of the action of track of different kinds, to learn the cause of defects in track and the opportunities for improvement. A few words on the influence of strength and stiffness of rail and of stiffness and uniformity of substructure on the quality and stability of track based on the tests and the analysis may be useful as having a bearing on discussions of track. It will be recalled that the tests have included rails from 56- to 136-lb. per yd. and stiffnesses of rail support with values of u from 500 to 6000.

In the previous discussions the part of the track below the rail has generally been referred to as the "rail support", especially in connection with the values of depression and moments in the rail. In connection with discussions on effects produced by track depression and moments in the rail and possible movements of the tie and of the ballast which may influence maintenance, the term "substructure" is used to include all the supporting structure below the rail. The two terms then refer to the same part of the track.

1. Size of Rail.

(a) *Moments and Stresses.*—It has been found that the moment developed in the rail by a single wheel load is dependent upon the stiffness of the rail and the stiffness of the rail support. For the single wheel load the moment (M_0) developed in 152-lb. rail averages 1.36 times that in a 90-lb. rail when u lies between 1000 and 6000 (see Table 31). The single trailer placed at some distance from the driving wheels and other wheels of a locomotive gives the nearest approach to a single wheel load; the moment M_T at the trailer of the Mikado locomotive of Table 32 and u of 1000 is almost the same with every weight of rail, while with u of 6000 the moment for 152-lb. rail is 1.26 times that for 90-lb. rail. The moment developed at the fourth driving wheel of the Mikado locomotive with a given value of u does not differ greatly for the several rail sections, the increase in the moment developed in the 152-lb. rail over that in the 90-lb. rail ranging from nothing at u of 1000 to 14 per cent at u of 6000. The moment developed in 152-lb. rail at an end wheel of the group of wheels of two coupled car wheels (the wheel developing the greatest moment in the rail) is about 25 per cent greater than that developed in 90-lb. rail (see Table 33). For any given moment the stresses in rail will

of course be inversely proportional to the section modulus of the rail section. Although no limiting rail stress may well be set without specifying the nature of the track and rolling stock and other conditions, it may be said for track in good condition and for the more common wheel loads and speeds and proper conditions of rolling stock that the longitudinal bending stresses in the medium weights of rail (say from 90- to 112-lb. sections) will not be excessive for ordinarily closely spaced groups of wheels. The lateral bending strength of the rail is also ample to resist the lateral moments ordinarily applied by side thrusts. The principal advantage of the heavier rail sections must then lie in other directions than longitudinal bending strength.

(b) *Wheel Bearing Pressure.*—Tests have not been made in this work to determine the effect of size of rail head and web upon the resistance to the bearing pressures of wheels. It is evident that a great variety of the worn contours of wheels and rails would be involved in any comprehensive tests. Nor has it been considered within the scope of the work to learn the relation between such pressures and such contours and the formation or extension of flaws or nuclei conducive to rail failure. Important as such information is, an investigation would need lines of attack different from those available to the Committee.

(c) *Tipping Stresses.*—The investigation has not given attention to the needs of the rail in resisting bending of the rail section upon itself laterally and the strength of the web and the base needed to resist the forces that act when the resultant of the supporting pressure at the bottom of the loaded rail has a position at or near one edge of the base of rail. This situation may exist when a wheel applies a large lateral thrust. It may also occur when the rail and tie-plate bearing is out-of-plane with the base of rail, and the difficulty may be aggravated when the out-of-planeness is in opposite directions at nearby ties. Frozen or unevenly thawed substructure or "heaved" track subjects the rail to abnormal conditions in these respects. In well ballasted and well surfaced track, particularly when the bearings of the tie-plate are in plane with the base of rail and when moderate lateral thrusts are applied by the wheels, the tipping moment generally will be readily resisted. Where large lateral forces are applied or where unfavorable track conditions such as those referred to above exist, high stresses and pressures will be developed, especially with the lighter rail sections.

(d) *Rail Stiffness.*—The greater stiffness of a heavier rail section has frequently been considered of value as carrying the load farther ahead or behind the wheel. This characteristic is related to stiffness of rail support, and the magnitude of u affects their relations in such a way that the influence of a heavier rail in giving any extension of support in front or back of a group of ordinarily closely spaced wheels has been found to be small. Besides, the average tie pressure at points between the front and back wheels of a group of ordinarily closely spaced wheels has been found not to differ much throughout the range of rail sections considered. In some respects the heavier sections have disadvantages in that they do not bend and twist and adjust themselves into new positions to fit abnormal conditions of track as much as the lighter sections may. It will be seen from the relative rail depressions that the greater stiffness of a heavier rail does not greatly affect the springiness or the resiliency of the track in taking sudden changes of load applied through defective rolling stock or the abnormal dynamic augment of an imperfect counterbalance. It is the stiffness of the substructure that mostly governs the springiness of track under a group of wheels, though the stiffness of the rail will take a local part in the spring, particularly when the increased load is on only

one wheel, as with dynamic augment of the main driving wheel. However, other advantages which accrue with the added stiffness of rail give value to the heavier sections.

(e) *Stability of Rail.*—The greatest value of heavier rail may be said to be the greater stability it gives to track. Stability implies the ability to maintain favorable conditions, to resist unusual or unexpected forces or loads, to overcome the variations. The greater stiffness of a heavier section aids in carrying loads over imperfectly tamped track and irregular supports; it resists lateral thrusts and lurches without undue distortion of alignment; it aids in maintaining proper surface. Even the added mass of the heavier rail is an element of stability. The added stiffness should be considered a help in reducing cost of maintenance.

It may be added that the value of increased size of rail will depend upon many circumstances, among them amount and nature of traffic, nature of substructure, wheel loads and speeds, and any economies involved in the situation. It is not to be expected that this value can be expressed quantitatively in formulas or equations, but studies of accompanying conditions should be helpful in forming a judgment.

2. Stiffness and Uniformity of Substructure.

(f) *Effect on Moment and Stress in Rail.*—As stated in Article 57 "Relations of Rail Properties, Rail-Support Stiffness and Wheel Spacing to Rail Stress, Moment and Depression and to Tie Load and Other Matters that Influence the Durability and Upkeep of Track", the moment developed in a given rail under a single wheel load is decreased considerably with increased stiffness of the substructure using the term substructure to include everything below the rail. In Table 31, the moment developed by a single wheel load when u is 6000 is .64 times that when u is 1000 for both the 90-lb. and the 152-lb. rail. For the trailer (the wheel having spacing conditions approaching those of a single wheel) the moment (M_T) (see Table 32) with u of 6000 is .74 times that with u of 1000 for 90-lb. rail, and the corresponding ratio for 152-lb. rail is .94. For the fourth driving wheel of the Mikado type locomotive (M_4), however, the effect of increasing the stiffness of the rail support is much less, the corresponding ratio of moments for 90-lb. rail being .86 and for 152-lb. rail .98. Somewhat similar ratios exist for the group of wheels of coupled cars. It may be said then that increased stiffness of rail support has relatively little effect on the moment in a given rail developed by one of a group of closely spaced wheels, but that the moment at the trailer may have considerable decrease in the case of the lighter rail sections. As the stress in a given rail is proportional to the moment developed, the conclusion given for moments may be applied to stresses.

(g) *Effect on Track Depression and Tie Load.*—For a group of wheels of ordinarily close spacing, the maximum depression of rail at a wheel may be said to vary nearly inversely as the stiffness of the rail support. For the Mikado type locomotive (see Table 34), the rail depression at the main driver (y_3) (the one giving the greatest depression) for the rail sections used is about 3 per cent greater at u of 6000 than the value found by taking one-sixth of the depression for the same rail at u of 1000. The maximum rail depression at a wheel of the trucks of two coupled coal cars given in Table 35 for u of 6000 is only slightly greater than the value found by taking one-sixth of the maximum depression at a wheel at u of 1000 for any of the rail sections. If the comparison had been made between moduli of 1500 and 3000 (a more usual range in stiffness) the agreement would have been closer. For many purposes then the maximum depression at the wheels of a group may be considered to be approximately inversely proportional to the stiffness of the substructure regardless of the weight of the rail.

The changes in tie pressure due to differences in stiffness of substructure on good track that is relatively free from play between rail and tie bed may be compared by using the rail depressions given by the analysis and the corresponding vertical pressure applied by the rail per inch of length of rail. It may then be considered that the tie pressure at any point is proportional to the product of the rail depression and the modulus u ($p = -uy$, equation (6)). For a group of ordinarily closely spaced wheels on high-grade track there will not be large differences in the magnitudes of the tie pressures at a given point between the end wheels of the group regardless of the stiffness of the track. For the Mikado locomotive of Table 34, it will be seen by multiplying y_3 by u that with all rail sections and all values of u the vertical pressure of the rail at the main driving wheel (the wheel having the greatest depression) does not vary much from 500 lb. per inch of length of rail. For the truck wheels of the two coupled cars of Table 35, by the same procedure it is found that with 90-lb. rail the maximum pressure under a wheel (either an end wheel of the group or an interior wheel) ranges from 360 lb. per in. for u of 1000 to 420 lb. per in. for u of 6000, while for the heavier rail sections the change is much less. However, when the pressures at the wheels and at a point between wheels along the distance between the end wheels of the group are averaged, the magnitudes of the average pressure vary but little through the range of u for any of the rail sections, even for all the sections and all the values of u. An approximate average value of the load on an individual tie at a given wheel may be found by multiplying the intensity (p) of the vertical pressure used above by the spacing of the ties center to center. Variations will be found for other types of locomotives and cars. For the usual types with ordinarily closely spaced wheels, however, for purposes of general comparison of tie loads it may be considered for track having only slight variation in play between rail and tie bed that the average tie load or even the maximum tie load under a given group of wheel loads will not vary greatly with different rail sections and differences in stiffness of rail support within the ranges here considered.

(h) *Effect of Springiness of Substructure.*—In Table 34 it will be seen that under the loading of this Mikado locomotive the maximum depression of the rail for the several values of u ranges from .47 to .08 in. The vertical travel of the springiness of the substructure under load for different values of u may be considered to vary fairly proportionately throughout this range. It is obvious that the greater vertical travel of the rail for the lesser stiffness may result in a smaller additional wheel pressure on the rail when acting to reduce longitudinal teetering of locomotives and cars and similar movements. On the other hand the smaller travel of the stiffer track is advantageous in damping direct vertical vibrations of cars. It will better take the unsprung load due to the dynamic augment of imperfect counterbalancing and also will not permit the locomotive itself to move downward through an appreciable distance during the application of this changing pressure. For rough track (considering the variations from a regular surface and alignment to be equal in the two cases) the stiffer track will better damp the vertical and lateral oscillations of the cars. Probably too it will better resist the forces applied by the imperfections of rolling stock.

(i) *Effect on Variability in Stress in Rail and on Irregularities in Rail Support.*—Tests on what is usually considered good track, such as those described in Chapter V, have shown marked variations in the play between rail and tie bed as the load comes on the track. This variability is relatively much greater with stiff substructure than with less stiff track equally well kept up. On stiff substructure the mean stress in base of rail has been found under static loading to vary from one-tenth of the average stress

along the rail to 1.75 times. The load carried by an individual tie has varied from nothing to 2.7 times the average tie load for the moderate wheel loads. Similar variations exist in the loads carried by the ballast. Doubtless much greater variations than those reported exist in track. This variability of distribution, of course, puts undue and irregular demands upon the substructure and adversely affects its durability and the cost of its maintenance. It is a prolific source of deterioration in track condition. Any approach toward uniformity in stiffness of substructure and freedom from uneven play between rail and tie support will result in an item in the economics of track maintenance worth consideration. That unevenness of support has been found to produce stress at one edge of base of rail nearly three times as great as the average mean stress should also be remembered.

In this connection it may be noted that variations in the application of the wheel load to the rail and the variable effects of speed will give still greater variability in the stresses in rail, both because of defects of the rolling stock and because of the effect of speed on the conditions here discussed.

(j) *Effect on Stability of Substructure.*—It is to be expected that the stiffness of the substructure in general will affect its stability and durability under traffic. The elements that go to make up stiffness or lack of stiffness in the substructure also affect the resistance or lack of resistance to heavy loads and to movements within the substructure. The less stiff substructure is more susceptible to injury, especially under heavy loads repeatedly applied. The action accompanying the greater vertical movements of the rail is more destructive of uniformity and stability in the track as a whole. The imperfect bearing of tie-plate on tie concentrates pressures on small areas and produces greater compressions and detrusions into the wood. The unevenness of bearing of tie on ballast (either in a direction across or along the tie, not considering the middle part of the tie length) also increases the concentration of pressure on the ballast and even the detrusion. Even the greater individual loads found at individual ties along the track increase the general depression of the rail over that obtaining with more nearly uniform distribution. The nature of the material forming the ballast necessarily affects the stiffness; and particles of such smoothness or softness and such size or gradation as to move easily on one another give greater depression. Qualities affecting stability show themselves in other ways.

It is also apparent that the magnitude of the vertical movements affects the stability and durability of substructure under heavy traffic. A substructure whose make-up permits large vertical movement under a given tie load does not have the qualities to resist deterioration of structure and especially unevenness of deterioration. The action of a substructure that gives a vertical depression of .4 in. may be expected to give way under the application of millions of groups of car wheels and a corresponding number of ups and downs, where one giving a depression of .1 or .2 in. will remain in fair condition. This is especially true in certain parts of the substructure. In other words, the conclusions of experience with different track substructures are borne out by an examination of the loads and conditions to which they are subject.

Still another way of considering the value of stiffness and stability of the part of the track below the rail may well be mentioned. In a substructure of low stiffness (small value of u), a part of the greater depression under load, as compared with stiffer substructure, is due to uneven bearing over the tie-plate and to the greater detrusion or compression of the tie caused by this concentration of pressure and to flexure of tie before the tie reaches its bed along its length and a part is due to the variation in pressure

from tie to tie due to differences in play between rail and tie and tie and its bed. Another part of the remainder is due to the lack of uniformity of distribution of pressures below the ballast along the track. With a low modulus, especially with a shallow depth of ballast or with unconsolidated ballast, the pressures on the roadbed under the ballast at a tie may be much greater than those between ties, so that a greater compression of ballast and roadbed will occur than for uniformly distributed pressures. Besides, the concentrations of pressure at certain points may exceed the permanent resistance of the material to repeated application of pressures, resulting in uneven movement of the particles over one another. The effects may be expected to be related to the magnitudes of the depression and to the energy applied to the substructure. The loss of applied energy through slight inelastic movements of particles among themselves and by abrasion and consolidation may increase the variability of the distribution of pressures on the ballast and roadbed along the track. These effects will be influenced by the magnitude of the track depression.

Since the pressures on the ties produced by a group of wheels carrying given loads are approximately the same regardless of the value of u and the size of the rail section, and since the energy put into the depression of the rail and the substructure by the load of the group of wheels may be considered to be equal to one half of the product of u and the average rail depression multiplied by the length of rail depressed, the energy so exerted may be said roughly to be inversely proportional to the value of u. With u of 3000, half as much energy then is applied to the rail and ties and ballast as with u of 1500. As the loss of energy and the injury to track through movement among the parts and the particles may be expected to vary in some way with the amount of the energy applied to the structure, less injury is given to line, surface, and uniformity of track when the substructure is stiff than when it lacks requisite stiffness. This is only another way of coming to the conclusion that, granting other requisites such as smoothness and uniformity of track, the stiff rail support has advantages in matters of maintenance, durability and stability, which are highly worthy of consideration.

61. **Advantages of High Grade Track.**—In Article 57 "Uniformity and Variability in Track"* of the Fifth Progress Report the need for uniformity in elasticity and stiffness of the rail support in track was discussed and the disadvantages of variability in the supporting resistance were considered. The tests described in the present report furnish further important data on the effects of variability on the action of the track and its resistance to the variable loads applied under traffic conditions. They throw light on the elements that will aid in prolonging the life of track and decreasing the expense of maintenance. The elements entering into the advantages of high-grade track are mostly obvious, but for helping to keep in mind their nature and value it may be well to repeat statements about some of them.

Regardless of sufficiency of strength in a rail the greater stiffness of the heavier rail is useful in reducing the twisting movement of the rail and in distributing the variable effects of this twisting over the ties; it thus gives more nearly vertical loads on ties that have uneven support along their length or width or otherwise have irregular supports. The stability of track given by the heavier rail is an element of value that should receive full consideration. The greater reserve capacity against unexpected and excessive variability in the loads applied and the improvement in the support afforded are of real value.

* Proceedings, A.R.E.A., Vol. 31 (1930), p. 325.

Giving the rail an inclination from the vertical inwardly of the track has been found to improve the bearing of wheel on rail and to give a better distribution of the stresses through the rail section to the tie-plate. An inclination of 1 in 20 best fits the standard coning of wheels. However, the use of 1 in 40 has been found to give advantages over a vertical position.

Evenness of bearing of rail on tie-plate and of tie-plate on tie is a most important element in giving quality and stability to track. Unevenness of bearing, out-of-planeness with the bases of the two rails, and eccentric position of the resultant of the bearing pressure have marked influence on stresses in rail, deterioration of tie wood, and concentrations of bearing pressure on the ballast bed of the tie. Even apparently small variations in bearings may give troublesome results. Uniformity in dimensions of ties and reasonable straightness are elements of importance. Obviously adequate and uniform bearing bed on the ballast is an essential to uniformity of support. Solidity and uniformity of roadbed of course are assumed.

Uneven play between rail and tie bed at nearby ties results in irregularities in the stresses in the rail and likewise in the loads carried by individual ties. The high tie must be depressed before the remaining ties take load, and under the full loads of a group of wheels the higher ties will carry a larger share of the load than will those that were the lower ones. With a stiff ballast bed traffic will not permanently depress the high ties to give uniform bearing. As a result of the variability of the bearing surface, some ties may carry no load and others two or more times the average load. Observations on track show that as the stiffness of the track substructure has been increased in recent years and the rail support given greater solidity and stiffness the magnitude of the variability of this play between rail and tie bed in ordinarily well-kept track has not changed much. The unloaded rail may rest on four or five ties in a rail length and the varying play referred to may be .05 in. or .10 in. or even more. In a track with stiff substructure the resulting variation in load will have a greater proportionate effect than in a less stiff track. For a track developing a net rail depression of .40 in. under a group of given wheel loads, an unevenness of play of .10 in. may result in a range of tie load perhaps from .75 to 1.25 times the average load. With a stiffer substructure and the same unevenness of play, one having an average net depression of .10 in. under the same load, the variation in tie load would be greater, ranging from 0 to 2.0 times the average load or more. A corresponding variation in stress in rail and other demands on the track will also be found.

It is evident that the greater stiffness in track substructure obtained in recent years contributes to a greater variability in moments and stresses in rail and in the distribution in tie and ballast loads in what is considered well-kept track. All observations emphasize the need and the value of exercising great care in obtaining reasonable uniformity in the condition of the substructure of track. It is apparent that new and better means should be devised for ensuring absence of variations in play between rail and tie bed and for securing uniformity of stiffness in the tie and ballast support. The call for improvement in uniformity applies to both medium and heavy rail, and should not be neglected even with light rail.

Machine tamping without proper control will fail to produce reasonable uniformity. Irregular play between rail and tie bed may soon develop in the track under usual conditions of tamping. To meet this difficulty new and better means should be devised to

know when adjacent ties or groups of ties are evenly tamped, and ways should be provided for checking results of maintenance work. The track should be put in such condition that each tie will carry its share of load. It should become an accepted principle of practice that absence of variability is a test of workmanlike maintenance.

The effectiveness of deep, consolidated ballast in distributing load and in minimizing the consequences of imperfect conditions in the track above it was referred to in the Fifth Progress Report as an element of financial value in the maintenance of track. Adequate depth and solidity are instrumental in providing uniformity of resistance both at a local group of ties and between one group and another some distance away. The thick bed of consolidated ballast in some ways acts somewhat like a beam and thus aids in providing stability and uniformity (see Fifth Progress Report, Proceedings, A.R.E.A., Vol. 31 (1930), page 327).

It is usually accepted that smoothness of track is a desideratum. The efforts toward gaining and maintaining uniformity of track under load herein suggested are steps toward improving smoothness. It is obvious that smoothness of track helps to reduce the forces and blows applied by rolling stock (whether the rolling stock is in good condition or poor) and thus in this way the needs for maintenance are decreased. Any improvement which reduces variations in line and surface existing under train loads not only gives more uniform stresses and pressures on rail and tie and ballast, as heretofore described, but it aids in producing a more nearly uniform straight-forward motion of the wheels along the track (reducing the side-to-side movement of the cars with flanges of wheels first against one rail and then against the other and decreasing the resulting frictional movement of both flanges and treads) and thus reduces wear of rail and variation of pressure on tie and ballast—at the same time giving relief from similar troubles in the rolling stock itself. Similarly, the tractive resistance caused by uneven or irregular action of the rolling stock may be expected to be lessened somewhat over that of less smooth track, though except when compared with rough track this effect will be small in proportion to the total resistance, for the journal friction and the air and wind resistances constitute by far the largest part of train resistance.

The higher speeds now demanded for both passenger and freight trains require uniformity of surface under load for longer distances along a track. The vertical and horizontal oscillations of locomotives and cars generally have nearly the same period of oscillation for different speeds, and for the high speeds uniformity is therefore needed over long stretches of track. This need as well as the possible cumulative effect of local variations puts more severe demands on high-speed track in a number of ways than are found for slower speeds.

In a general way there is mutuality in the effect of the condition of the track and rolling stock which should be recognized—that which injuriously affects one may have a similar effect on the other. Roughness of loaded track in line and surface increases wear and maintenance of rolling stock as well as track, and imperfections of wheels and trucks and running gear and attachments to body that may interfere with straight-forward motion and uniformity of wheel load will influence the wear of both cars and track. On the other hand, such matters as out-of-roundness of wheels and the dynamic augment of unbalanced rotating parts may have a far more detrimental effect on the track than on the rolling stock. However, the interrelation of the track and the rolling stock is of paramount interest and should always receive adequate consideration.

The discussions of this chapter are intended to apply particularly to straight track. Although curved track has many special characteristics and requirements, much of the discussion it will be seen also applies to the curved track.

Finally, it may be said that the advantages and necessities for high-grade track are such as to warrant a more thorough study of the elements entering into its construction and maintenance and the means of obtaining it easily and economically.

Respectfully submitted,

THE SPECIAL COMMITTEE ON STRESSES IN RAILROAD TRACK,

A. N. TALBOT, *Chairman.*

REPORT OF COMMITTEE XX—UNIFORM GENERAL CONTRACT FORMS

F. L. Nicholson, *Chairman;*
C. Frank Allen,
E. H. Barnhart,
W. H. Brameld,
B. S. Dickerson,
R. P. Eubank,
W. D. Faucette,
F. H. Fechtig,
J. P. Hanley,
B. Herman,
J. C. Irwin,
A. C. Jackson,
J. S. Lillie,
S. L. Mapes,
A. A. Miller,
O. K. Morgan,
C. B. Niehaus,
H. A. Palmer,
W. G. Nusz, *Vice-Chairman;*
W. M. Post,
J. A. Russell,
Chas. Silliman,
Huntington Smith,
W. R. Swatosh,
J. S. Thorp,
C. A. Wilson,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully reports on the following subjects:

1. Revision of Manual—Appendix A.

The Committee has no revisions to recommend.

2. Form of Agreement for the Purchase of Electrical Energy in Large Volume (such as required for traction purposes), collaborating with Electrical Section—Appendix B:

This subject was assigned in 1928, and in the preparation of this Form of Agreement, the Committee has had the valuable and whole-hearted collaboration of the Electrical Section, through a sub-committee appointed for the purpose; authorities both from the production or selling side and the using or purchasing side, have been consulted and many suggestions have been received influencing the terms and conditions as written in the completed form now presented for adoption as Recommended Practice and for printing in the Manual.

3. Form of Conveyance of Title Granting the Right to Construct and Maintain Buildings over Railway Property—Appendix C:

This form has been very carefully prepared after studying all available contracts and conveyances and is submitted as information with the hope that members interested in the subject will carefully review and give the benefit of their views to the Committee.

It is recommended that the subject be continued.

4. Form of Agreement for Pipe Line Crossings under Railway Tracks—Appendix D; and

5. Form of Agreement for Use of Railway Property by Pipe Lines paralleling Railway, with Special Reference to Pipe Lines Carrying High Pressure Inflammable Oils or Gas, collaborating with Committee I—Roadway and Committee XIII—Water Service and Sanitation, Appendix D:

When the Committee began preparation of these forms, it came to the conclusion that one form could be prepared to cover both assignments, and the form now presented has been prepared in collaboration with Committee I—Roadway and Committee XIII—Water Service and Sanitation, and after several conferences with special committees of the American Petroleum Institute.

This Form is presented for adoption as Recommended Practice and for printing in the Manual.

Bulletin 360, October, 1933.

6. Form of Agreement with Public Authorities for Highway Grade Crossing Elimination or Separation, collaborating with Committee IX—Grade Crossings—Appendix E:

This Form of Agreement as prepared and submitted, covering both over and under pass grade separation, is very complete and worthy of your acceptance, but, following the practice of the Committee to give ample opportunity for discussion and suggestions, it is submitted as a progress report with the hope that the members will favor the Committee with such suggestions as they care to make for its betterment, that the Committee may present at the next convention for adoption, a form that will be most useful to you.

It is recommended that the subject be continued.

Respectfully submitted,

The Committee on Uniform General Contract Forms,
F. L. Nicholson, *Chairman.*

Appendix A

(1) REVISION OF MANUAL

C. A. Wilson, Chairman, Sub-Committee; C. Frank Allen, R. P. Eubank, J. C. Irwin, J. S. Lillie, A. A. Miller, W. G. Nusz.

Your Committee has no revisions to recommend at this time.

Appendix B

(2) FORM OF AGREEMENT FOR THE PURCHASE OF ELECTRICAL ENERGY IN LARGE VOLUME (SUCH AS REQUIRED FOR TRACTION PURPOSES)

W. G. Nusz, Chairman, Sub-Committee; W. H. Brameld, S. L. Mapes, W. M. Post and J. S. Thorp.

Your Committee presented a preliminary draft of the Form of Agreement for the Purchase of Electrical Energy in Large Volume in 1932, Bulletin 340. A joint meeting of the Sub-Committee of Committee XX and a Sub-Committee of Committee XVII of the Electrical Section, held this year, considered all of the comments and suggestions received and your Committee now submits a draft of the completed Form of Agreement and recommends its adoption as recommended practice and that it be printed in the Manual.

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FORM OF AGREEMENT FOR PURCHASE OF ELECTRICAL ENERGY IN LARGE VOLUME (SUCH AS REQUIRED FOR TRACTION PURPOSES)

THIS AGREEMENT, made this.....day of....., 19.... by and between....., a corporation organized and existing under the laws of the State of....., hereinafter called the "Power Company", and....., a corporation organized and existing under the laws of the State of....., hereinafter called the "Railway Company".

WITNESSETH:

WHEREAS, the Railway Company desires to purchase and take from the Power Company and the Power Company desires to sell and deliver to the Railway Company,

during the term hereof, electric energy (hereinafter called "energy") estimated to be initially about.....kilowatts of Billing Demand (as hereinafter defined) for electric operation of certain portions of the Railway Company's system comprising .....
....., all of which lines are located as shown on map dated....., designated.....
.....,
marked "Appendix A", attached hereto and made a part hereof, and for other purposes as hereinafter provided.

Now, Therefore, in consideration of the covenants and agreements herein contained, to be performed by the parties hereto and of the payments hereinafter agreed to be made, it is mutually agreed as follows:

Article I

TERM OF AGREEMENT

The term of this agreement shall be.....
(.....) years, commencing on....., or on such earlier date as the Railway Company may designate by written notice to the Power Company at least..... (.....) months prior to such earlier date; subject, however, to termination as provided in Article VIII.

The Railway Company shall have the right, at its option, to extend the original term hereof for a period of.....years by giving to the Power Company not later than.....months prior to the expiration of the original term, written notice of its election to make such extension.

Article II

OBLIGATIONS AS TO SUPPLY AND PURCHASE

For and during the term hereof the Power Company shall supply and deliver, and the Railway Company shall purchase and take from the Power Company, in accordance with and subject to the terms, provisions and conditions herein contained, the energy used within the territory hereinbefore defined, for or in connection with the electric operation of trains and for non-traction purposes connected with or incidental to the construction, maintenance, use and operation of the Railway Company's properties, whether occupied or used by it as a common carrier or otherwise, or leased or sub-leased to tenants or sub-tenants; provided, however, that;

> (Insert here the provisions as to proportion of requirements to be supplied; resale; limits of supply to tenants; generation at existing Railway Company plants; supply to other railways using the Railway Company's tracks; regeneration; increasing demands; and other provisions of special nature).

In the event of failure of the Power Company's supply of energy, the Railway Company shall have the right to use during such failure for any purpose energy acquired from any other available source.

Incidental flow of energy through the Railway Company's circuits from other power sources shall not be considered contrary to the intent of this article.

Article III

CHARACTER OF SERVICE

The energy to be supplied hereunder shall be in the form of.....
.....phase, ...wire, ...cycle, alternating current and at a normal voltage of.....volts per phase and/or direct current at a normal voltage of.....volts and at other voltages, frequencies or number of phases agreed upon by the parties hereto.

The frequency and voltage at the points of delivery shall be as constant as practicable, considering the characteristics of the Railway Company's load and the operating requirements of the Power Company's system.

Under normal conditions of operation on the Railway Company's system and on the Power Company's system, the voltage variation at the points of delivery shall not exceed .....per cent (.....%) above or below the normal voltage.

Article IV

CHARACTER OF LOAD

The type, arrangement and operation of the equipment used by the Railway Company in connection with the energy taken hereunder shall be such as will not materially interfere with the operation of the Power Company's system and service to its other customers.

The power factor of the Railway Company's system during periods of heavy demand shall not be less than.....per cent (.....%) lagging.

Article V

POINTS OF DELIVERY

The energy to be supplied hereunder shall be delivered by the Power Company to the Railway Company and measured at the following points:

(Railway Sub-stations, Power Company Generating Stations, Power Company Sub-stations, etc. Specify method of connection and division of ownership, operation and maintenance of facilities.)

Article VI

RATES AND PAYMENTS

Section 1. For each calendar month of the term hereof, the Railway Company shall pay to the Power Company the following:

(a) An amount of money known as the Primary Charge equal to.....
.....dollars ($.....) per kilowatt of Billing Demand for that month. Such Billing Demand shall be the Maximum Demand for the month ascertained in accordance with Section 2 of this Article, or.....per cent (.....%) of the greatest previous maximum demand during the last preceding twelve months or.....kilowatts whichever is the greatest; provided, however, that the Billing Demand for each month during the first year of said term shall be the actual Maximum Demand for that month and the Maximum Demand for each such month shall be ignored in determining the Billing Demand for any subsequent month, and further provided that the sum of the Primary Charges for the first year of said term shall not be less than.....dollars ($.....).

(b) An amount of money known as the Secondary Charge, equal to..... .....mills ($.....) per kilowatt hour of energy furnished hereunder during each month, subject to the addition or deduction of...../1000ths of a mill ($.....) per kilowatt hour for each.....cents (.....¢) of increase or decrease from the average delivered cost per unit of fuel of..... .....dollars ($.....).

(Note:—It may be desirable to have either or both the Primary and Secondary Charges in blocks. Also, consideration should be given to the effect of variations in labor costs and to the variations in cost per kilowatt hour at switchboard of hydro-electric plants.)

The number of kilowatt hours to be used in computing the Secondary Charge for any month shall not be less than.....per cent (.....%) of the equivalent of the Billing Demand for such month if used during each and every hour of that month.

Section 2. As soon as practicable after the end of each calendar month the Railway Company's Maximum Demand in kilowatts for such month shall be ascertained as follows:

From each of three days in the month there shall be selected one even clock hour which shall be the hour of greatest combined draft of the day from which it is taken; and said three days shall be such that the sum of the combined drafts of the three hours selected therefrom in the manner thus indicated shall be greater than the sum of the combined drafts of three hours similarly selected from any other three days in the month. One-third of the sum of the combined drafts of the three hours selected as aforesaid from each month shall be taken and considered as the number of kilowatts constituting the Maximum Demand.

Said combined draft during any even clock hour shall be the amount of energy measured in kilowatt hours, or shall be.....per cent (.....%) of the resultant integrated product of voltage and current, measured in kilovolt-ampere hours, whichever shall be greater, and shall be construed as representing a single quantity of energy, or.....per cent (.....%) of the resultant integrated product of voltage and current, as the case may be, taken hereunder at the several points of delivery just as though the various quantities were measured and integrated as one quantity at one point.

Maximum Demands occurring on Sundays, legal holidays, between noon and 11:00 o'clock on Saturdays, and between 11:00 o'clock any evening and 6:00 o'clock the following morning shall be ignored in determining the Billing Demand for any month.

If in any month the Railway Company shall require an abnormal energy supply caused by excessive or congested traffic beyond that usually handled by the Railway Company or due to storm, accident, complete or partial failure of the Power Company's supply of energy, derangement of the Railway Company's power facilities, or any other emergency condition, the Power Company will, if it has sufficient capacity available at the time, supply such abnormal demand, provided the Railway Company shall give the Power Company prompt notice of such abnormal demand by telephone or otherwise, confirming such notice by letter within forty-eight (48) hours. The Railway Company agrees, however, to promptly reduce the demand to normal upon notification from the Power Company that such reduction is necessary to preserve the general service of the Power Company. In ascertaining the Maximum Demand for such months, hours, in which such abnormal demand or demands occur shall not be selected unless such abnormal demands occur in.....or more consecutive days; and in

the latter event, hours in which such abnormal demands occur may be selected from any of such consecutive days following the.....of such consecutive days, but such hours shall be ignored in determining the Billing Demand for any month subsequent to the month in which such abnormal demand occurred and shall be ignored in determining the minimum number of kilowatt hours to be used in computing the Secondary Charge for that month.

Section 3. The Railway Company shall have the right at all reasonable times to examine and make copies of all meter and other records of the Power Company used in the computation of bills rendered hereunder.

Section 4. All payments for charges incurred under the provisions of this agreement during any calendar month shall be due and payable..... (.....) days after receipt of the bill therefor.

In case payment of a charge be not made on or before the day upon which it becomes due, interest shall accrue upon such charge at the rate of..... per cent (.....%) per annum from the date on which it becomes due. In case the Railway Company questions the correctness of any bill it shall nevertheless make payment of the full amount thereof. When decision or agreement with respect to the questioned bill is reached, the Power Company shall refund the overpayment, if any, together with interest thereon at the rate of.....per cent (.....%) per annum from the date on which such bill was originally paid.

Article VII

METERING

Section 1. All energy furnished under this agreement shall be measured at the points of delivery by meters to be installed and maintained by the Power Company at its expense.

Section 2. The instruments to be installed by the Power Company shall be of a standard type and manufacture and shall accurately measure the energy in electric units and periods of time as required by the terms of this agreement. The Railway Company shall have the right to be represented at the readings of these instruments and at the testing, adjusting or changing thereof.

Section 3. All meters shall be tested and calibrated by the Power Company every .....by comparison with accurate standards, and if as the result of any test a meter shall be found to be inaccurate, it shall be restored to an accurate condition or an accurate meter shall be substituted by the Power Company. Either party to this agreement shall have the right to require that a test be made of any meter at any time. The party desiring such test shall make request therefor in writing upon the other party and thereupon such meter shall be tested and calibrated by the Power Company, and if it shall be found inaccurate it shall be restored to an accurate condition or an accurate meter shall be substituted by the Power Company. If as a result of any test any meter shall be found to register in excess of two per cent (2%) either above or below normal, then the readings of such meter previously taken shall be corrected, but no such correction, either in respect to demand or kilowatt hours drawn or consumed, shall extend back beyond thirty (30) days previous to the date on which such inaccuracy shall be discovered by such test, and if during such previous thirty (30) days one or more prior tests shall have been made under the provisions hereof, then no such correction shall extend back beyond the date of the last of such prior tests.

The Power Company shall give to the Railway Company reasonable notice of the time when any test will be made as hereinbefore provided.

If any special test of any meter shall be made at the request of the Railway Company with the result that such meter shall be found to register correctly or within two per cent (2%) of normal, then the Railway Company shall bear the expense of such test. The expense of all other tests shall be borne by the Power Company.

Article VIII

INTERRUPTION, DEFAULT AND TERMINATION

Section 1. The Power Company shall use all due diligence in providing a regular and uninterrupted supply of energy, but in case the supply of energy shall be interrupted, be defective or fail for any cause, the Power Company shall not be liable therefor, except as otherwise herein provided.

If, however, such failure occur, the Railway Company shall be entitled to a proportionate and equitable deduction from the Primary Charge for the month in which said failure occurred, provided claim for such deduction be made within thirty (30) days after the end of the month in which the failure of delivery occurred.

Section 2. If in any month the Power Company shall be unable to deliver energy to the Railway Company, either in whole or in part, as required to be delivered by it under the provisions of this agreement, or the Railway Company shall be prevented from operating its regular train service, either in whole or in part, by strike, riot, insurrection, civil or military authority, fire explosion, act of God, railway accident, the complete or partial failure of the supply of energy from any other source, or by any other cause reasonably beyond its control, and if such inability and/or prevention shall cause the Railway Company's consumption of energy in such month to fall below the minimum amount specified in item (b) of Section 1 of Article VI hereof, then the number of kilowatt hours to be used in computing the Secondary Charge for such month shall not be less than the sum of

(a) the number of kilowatt hours which would equal..... per cent (.....%) of the total number of kilowatt hours which the power represented by the Billing Demand for such month could produce, if exerted during each and every hour of that month except the hours in which such inability and/or prevention occurred, and

(b) the number of kilowatt hours supplied during the hours in which such inability and/or prevention occurred.

Section 3. It is recognized that the Railway Company must receive from the Power Company a regular and uninterrupted supply of energy in accordance with the provisions of this agreement, in order to make this agreement of value to it; and if for any reason interruption of such supply of energy shall be so frequent or of such duration as to interfere materially with the operation of its lines of railway, or if the amount, quality or character of the energy delivered hereunder shall not be in accordance with the provisions of this agreement, then the Railway Company may notify the Power Company thereof in writing, specifying the grounds of complaint, and the Power Company shall forthwith remedy the trouble so specified and provide a full, regular and uninterrupted supply of energy in accordance with the provisions of this agreement. If the Power Company shall fail to do so with reasonable diligence and promptness and in any event within ninety (90) days from the date of such notice, the Railway Company shall have the right at its option to terminate this agreement by giving to the Power Company thirty (30) days' notice in writing of its intention so to do, stating in such notice the date of proposed termination, and this agreement shall terminate upon the date of termination

specified in said notice; provided, however, that if on any earlier date the Railway Company shall be able to obtain elsewhere the necessary energy required for the operation of its railway lines and shall give the Power Company notice in writing of such fact, this agreement shall terminate upon the date of such later notice.

Section 4. The Railway Company shall have the right at its option to terminate this agreement if the rates and charges herein specified shall be increased, pursuant to or by operation of law; also the Railway Company shall have the right at its option to terminate this agreement without assigning any cause therefor at the end of the .....year of the term or at the end of any twelve (12) months' period thereafter. In case of any termination as provided for in this section, the Railway Company shall give to the Power Company not less than eighteen (18) months' notice in writing of its intention so to do, and this agreement shall terminate upon the date of termination specified in such notice; provided, however, that upon such termination before the end of the original term, the Railway Company shall purchase from the Power Company such conversion and transmission apparatus and facilities as shall be then in use solely for the delivery of energy to the Railway Company under this agreement. The purchase price shall equal the actual cost less the sum of annuities of .....per cent (.....%) per annum of such actual cost from the time such apparatus and facilities shall first have been placed in operation for the sole benefit of the Railway Company to the date of termination. The actual cost of apparatus and facilities installed at the commencement of the term hereof for the sole purpose of delivering energy hereunder is hereby agreed to be.....Dollars ($.....) (Description of apparatus and facilities and the cost thereof to be appended if so desired.)

Section 5. If the Railway Company fails to pay any bill of the Power Company as provided for in Article VI within ninety (90) days after such bill is due, the Power Company shall have the right to terminate this agreement by giving to the Railway Company not less than thirty (30) days' notice in writing of its intention so to do, stating in such notice the date of proposed termination, and this agreement shall terminate upon the date of termination specified in said notice.

Section 6. If the type of the equipment or if the operation of the equipment used by the Railway Company in connection with the energy taken hereunder interferes materially with the operation of the Power Company's system and service to its other customers, then the Power Company may notify the Railway Company in writing specifying the grounds of complaint and the Railway Company shall forthwith remedy the trouble so specified. If the Railway Company shall fail to do so with reasonable diligence and promptness and in any event within ninety (90) days from date of such notice, the Power Company shall have the right to terminate this agreement by giving to the Railway Company not less than thirty (30) days' notice in writing of its intention so to do, stating in such notice the date of proposed termination, and this agreement shall terminate upon the date of termination specified in said notice.

Article IX

REDUCTION IN RATES

If at any time during the term of this agreement, the Power Company shall deliver energy to any other consumer for service under similar conditions at a total rate or charge which shall be lower than that hereinbefore given to the Railway Company, and such lower rate or charge shall not be justified by different conditions of service, making the cost of production and delivery to such other consumer relatively less than to the

Railway Company (and the burden of proving such different conditions of service justifying the lower rate or charge shall be upon the Power Company), then and in that event and so long as such lower rate or charge shall be given to such other consumer while this agreement is in force, the Railway Company shall be entitled to a reduction in its said rate or charge equal to so much of the amount of the difference between such lower rate or charge and the Railway Company's said rate or charge as shall not be so justified.

If at any time during the terms of this agreement, the Power Company shall make a change in their method of generating, purchasing or transmitting electrical energy and if this change in the method of generating, purchasing or transmitting electrical energy shall result in a reduction in the cost per unit of electrical energy to the Power Company in excess of ten per cent (10%), the Railway Company shall be entitled to a corresponding reduction in the charges made for electrical energy purchased in accordance with this agreement.

Article X

ARBITRATION

In case any question arises under this agreement or concerning the subject-matter thereof, upon which the parties hereto cannot agree, such question shall be settled by a sole disinterested arbitrator, to be selected jointly by the parties to this agreement, and if they fail to select such arbitrator within..... (.....) days after demand for arbitration is made by either party hereto, then such arbitrator shall be appointed by the Judge of the.....Court of.....

The expense of arbitration shall be apportioned between the parties hereto, or wholly borne by either party, as may be determined by the arbitrator.

Article XI

GENERAL

Section 1. The Power Company shall have right of access to the premises of the Railway Company at all reasonable times during the period of this agreement, and on its termination, for the purpose of reading meters, inspecting or repairing appliances used in connection with its service, removing its property, or for any other purpose proper under this agreement.

The Railway Company shall not permit access, except by authorized employees of the Power Company, to the meters or other appliances of the Power Company, nor interfere with the same, and their safekeeping shall be provided for by the Railway Company.

Section 2. Whenever either party shall install any conduit, cable, wire or other apparatus or equipment in or upon the premises of the other party under any provision hereof, the party owning the same shall have the right, upon giving due notice to the other party, to repair or remove such apparatus or equipment at any and all reasonable times; provided, such repair or removal shall not interfere with the carrying out of this agreement; and upon the termination of this agreement by lapse of time or otherwise, such party shall at its own cost and expense, remove promptly and permanently any and all property owned by it upon the premises of the other party. Upon the removal of any property by either party from the premises of the other party as aforesaid, the party removing the same shall at its own cost and expense restore said premises to the same or as good condition as existed prior to the placing of said property thereon.

Section 3. The Railway Company agrees to indemnify and save harmless the Power Company from all cost, expense or liability for damages, which may arise or result from the use, care or handling of the energy delivered hereunder after the same shall have been delivered to the Railway Company at the points of delivery specified in Article V hereof, or from the presence upon the premises of the Railway Company of any appliances of the Power Company, except that the Power Company shall be responsible for all claims of its own employees, agents or servants.

The Power Company agrees to indemnify and save harmless the Railway Company from all cost, expense or liability for damages which may arise or result from the use, care or handling of the energy delivered hereunder before the same shall have been delivered to the Railway Company at the points of delivery specified in Article V hereof, or from the presence upon the premises of the Power Company of any appliances of the Railway Company, except that the Railway Company shall be responsible for all claims of its own employees, agents or servants.

Section 4. Any waiver or any number of successive waivers of any of the rights that may accrue to either party hereto through the default of the other party in keeping and performing any of the terms or obligations of this agreement shall not estop the party so waiving the default from asserting and having the benefit of its rights in accordance with the terms of this agreement upon any other or subsequent default, but at any time during the life of this agreement either party shall have the rights and benefits herein provided in case of default by the other party, without regard to any prior waivers or the number or time of such prior waivers.

Section 5. This agreement shall inure to the benefit of and be binding upon the legal representatives and successors of the parties respectively; provided, however, that this agreement shall not be assigned by the Power Company unless such assignment shall be made to another company having equal facilities to effectually perform, and which shall covenant to perform, the obligations herein of the Power Company.

In Witness Whereof, the parties hereto have executed this agreement in..... .....the day and year first above written.

The ..... Company

By .....
President

Witness .....

(Seal—Power Company)

Witness .....

Attest .....
Secretary

The ..... Company

By .....
President

Witness .....

(Seal—Railway Company)

Witness .....

Attest .....
Secretary

Appendix C

(3) FORM OF CONVEYANCE OF TITLE GRANTING THE RIGHT TO CONSTRUCT AND MAINTAIN BUILDINGS OVER RAILWAY PROPERTY

R. P. Eubank, Chairman, Sub-Committee; W. D. Faucette, O. K. Morgan, H. A. Palmer, Huntington Smith.

Your Committee reports progress with Form of Conveyance of Title Granting the Right to Construct and Maintain Buildings over Railway Property.

Action Recommended

That this be accepted as a progress report and printed in the Proceedings as information and the basis for criticism and suggestions, and the subject be continued.

THIS INDENTURE, made this ..... day of ....., 19...., by and between ....., a corporation organized and existing under the laws of the State of ....., Grantor, and ....., a corporation, organized and existing under the laws of the State of ....., Grantee,

WITNESSETH: That for and in consideration of the sum of .... Dollars ($.....), and other valuable considerations, the receipt of which is hereby acknowledged, the Grantor conveys with ..... Warranty unto the Grantee, the following described land, property and space situate in the City of ....., County of ....., State of ....., to-wit:

(a) All the land, property and space at and above a horizontal plane ..... feet above ..... datum within and bounded by surfaces formed by projecting vertically upward from the surface of the earth the boundaries of the land bounded and described as follows: Beginning at the .... (Insert description) .... to the point of beginning, and containing ..... square feet, more or less, being a part of Lot No. ....., Block ....., of ..... Sub-Division of the City of ....., and as shown on map hereto attached, designated as ....., dated ....., of the ..... Engineer's office, and made a part hereof.

(b) Certain rights of support for structure as hereinafter set forth.

The Grantor's premises as aforesaid, below ..... elevation, not herein conveyed, are hereinafter referred to as the "ground space" and the term "..... datum" wherever used in this conveyance means the datum as now established by .....

The said ground space may be occupied and used by the Grantor for the construction, maintenance, use, operation and renewal of its railway tracks and facilities as they now exist or may hereafter be constructed for the operation and use of engines, trains, cars and other equipment and for all other purposes incident thereto; also for such other and different purposes as the Grantor, its successors or assigns, may from time to time or at any time hereafter deem advisable; and the Grantor, its successors or assigns, reserves the right, at its option, to lease, encumber or sell the ground space, subject to the

rights hereinafter granted to the Grantee, and also hereby covenants and agrees that such occupation and use by it of said ground space shall at all times be exercised in such manner as not to interfere with the rights in and to such ground space which are hereinafter granted in this conveyance to the Grantee.

The Grantor hereby further gives and grants to the Grantee, and to its successors or assigns, the perpetual right to construct, install, maintain and renew within the ground space, foundations, columns and bracing for the support of any buildings or other structures to be erected by the Grantee, all to be located and constructed in conformity with plans hereto attached and made a part of this conveyance and identified by the signatures of the Chief Engineer for the Grantor and the Architect for the Grantee, and to be designed, constructed, maintained and installed so as not in any manner to interfere with the Grantor's construction, maintenance and operation of its present tracks and facilities or tracks and facilities that may hereafter be constructed. The said right granted as aforesaid to the Grantee shall be and constitute an easement in and over said ground space perpetually running with the lands and premises hereby conveyed.

(Here insert any further grant or grants of easements in the ground space for sewers, pipes, tunnels, subways, etc., necessary or peculiar to the particular situation.)

The Grantor hereby reserves to itself, and to its successors and assigns, the right, without compensation to the Grantee, to attach wires, ducts, pipes, conduits and other apparatus and equipment and their supports to the columns, pedestals, inside of walls or underside of any buildings or other structures which may be erected by the Grantee, in, over or upon the ground space, and to repair, maintain and renew or to change the location of said wires, ducts, pipes, conduits and other apparatus and equipment and their supports.

And the parties hereto, in consideration of the premises, and of the mutual covenants herein contained, do further covenant and agree as follows:

(1) The Grantor covenants and agrees that it will, at the Grantee's sole expense, make such changes in the location of its tracks and structures within the ground space as shall conform to the locations thereof shown upon the plans attached hereto, and that it will, so far as may be reasonably practicable without undue interference of its service, co-operate in every reasonable way with the Grantee, to the end that the Grantee may promptly begin and prosecute to early completion the work of constructing its supporting foundations and columns.

(2) The Grantee covenants and agrees:

(a) That before erecting any buildings or other structures or foundations, columns or bracing therefor in, over or upon the ground space, it will submit detailed plans and specifications to the Chief Engineer of the Grantor, which shall conform in all respects as to size, location and dimensions within the ground space to the plans hereto attached, and shall provide a vertical clearance of not less than ..... feet above the top of the rails as they now exist; and the construction of such buildings or other structures or foundations, columns or bracing shall be subject to the approval and reasonable inspection, control and direction of said Chief Engineer.

(b) That in all its construction it will perform the work with the least possible interference with the property of and the operations of the Grantor and will, during said construction, provide, at its own expense, adequate and safe support for the Grantor's tracks and other facilities in strict accordance with the requirements of the Chief Engineer of the Grantor; the Grantor, however, reserving the right at any time to do all or

any part of the work necessary in connection with the proper support of its tracks and other facilities at the sole cost and expense of the Grantee.

(c) That any buildings or other structures erected in, over or upon the ground space shall be fireproof and shall be thoroughly waterproof and drained in the building drainage system, and that no water, liquid or waste of any character shall be permitted to drain or leak into the ground space.

(d) That it will make no alterations or changes in said buildings or other structures, which will increase the loads carried by the supporting foundations and columns in, over or upon the ground space without the written consent of the Grantor first had and obtained; that plans and specifications showing any such proposed alterations or changes shall be submitted to the Grantor for approval upon the application for such consent; and that all alterations or changes made with the written consent of the Grantor as aforesaid shall be made at the sole cost of the Grantee under the control, direction, inspection and approval of the Chief Engineer of the Grantor; also that proposed alterations and changes shall be first approved by the municipal or other governmental authorities having jurisdiction, and in accordance with such lawful orders and regulations as said authorities may from time to time make in regard thereto.

(e) That it will not permit the loading of any of the floors of any buildings or other structures at any time erected in, over or upon the land, property and space so conveyed, or any portion or portions of said floors, beyond the loads which the same will safely support, nor beyond the loads permitted by the municipal building code.

(f) That it will provide, construct, operate and maintain, at its own cost and expense, a system of ventilation for the purpose of exhausting smoke, other fumes and gases from locomotives or any cause whatsoever in the ground space, said system to include, among other features, openings over every track leading into smoke chambers which shall lead into a vertical stack or stacks in the buildings, so that the smoke, fumes and gases shall exhaust through the top of the buildings, the entire plan, arrangement and construction to be subject to the approval and satisfaction of the Grantor.

(g) That in the event of the use at any time, by the Grantor or other transportation companies using its station, of electricity or any other means of motive power for the running of locomotives, cars, trains or other facilities upon its tracks in the ground space, neither the Grantor nor said transportation companies shall be liable to the Grantee for any interference due to such use with telephone, telegraph, radio or other electrical apparatus or other instrumentalities of any kind or nature used by the Grantee or by others using or occupying said granted premises.

(h) That it will keep the buildings or structures sufficiently covered by fire insurance, and will not conduct or permit others to conduct in said buildings or structures any business in violation of any Federal, State or municipal law, and will keep the buildings or structures in such condition as the Board of Health or other lawfully constituted authority may require, free of all cost to the Grantor, and in accordance with the rules and regulations of the National Board of Fire Underwriters.

(i) That it will indemnify and save harmless the Grantor from and against any loss, damage, cost or expense by reason of the Grantee's failure in any respect to perform its covenants in this indenture entered into, or to comply with any obligation imposed upon it by law with respect to the land, property and space so conveyed, or by reason of any accident, loss or damage resulting to person or property in consequence of any act or omission by the Grantee in, over or upon the land, such as may arise or in any manner grow out of the construction, maintenance, presence, use or removal of any buildings or other structures placed over or upon the property and space so conveyed, and no approval by the Grantor of plans, buildings or other structures in, over or upon the land,

property and space so conveyed shall be construed to waive the foregoing covenants to save and keep the Grantor harmless and indemnified.

(j) That it will indemnify and save harmless the Grantor from all claims for property loss or damage, death or personal injury which may be suffered or sustained by the Grantee, its agents, servants, employees, invitees, licensees or tenants, on, over or upon the property herein conveyed, or in the buildings or structures located thereon, in connection with the exercise of the privileges herein granted, arising from any cause whatsoever.

(3) All general taxes levied and assessed against the ground space herein retained and the land, property and space herein conveyed,

(Here insert a provision for distribution of aforesaid taxes.)

The Grantee covenants and agrees to pay all taxes and assessments, general and special, of every kind and nature whatsoever levied upon any buildings or other structures at any time placed by the Grantee upon the land, property and space herein conveyed.

(4) All the covenants, conditions and undertakings herein shall inure to the benefit of and be binding upon the legal representatives, successors and assigns of the parties respectively, and shall be construed as covenants running with the land.

In Witness Whereof, the parties hereto have executed this indenture the day and year first above written.

Witnesses	(Signatures)
	.....
.....	.....
	(Room for Seal)
.....	.....
	.....
.....	.....
	(Room for Seal)
.....	.....

SUGGESTIONS FOR OTHER CONDITIONS THAT MAY APPLY AT CERTAIN LOCALITIES

1. The question of heating may come up and either company could put in a plant and serve heat to the other.

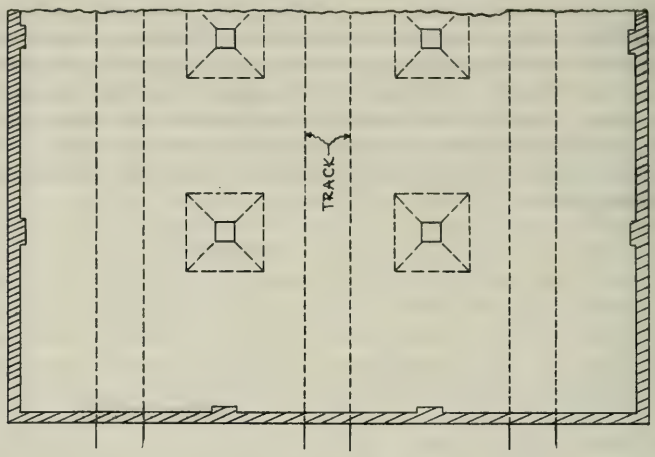
2. The question of maintaining approaches and streets would really be a part of the structure, but if there are any unusual approaches, there could be a clause added to take care of this.

3. Water supply and sprinkling system would develop in some localities and not in others. It might be well to consider which company should put in the system and allow the other to use same.

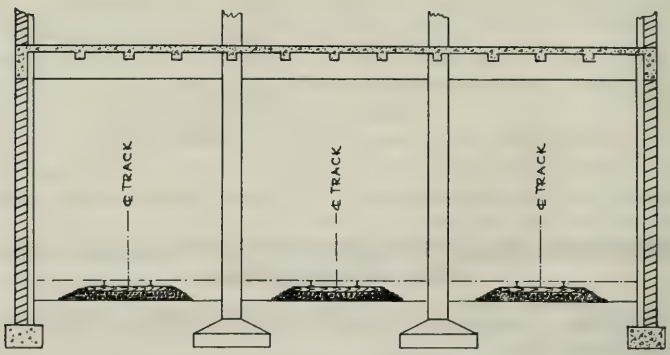
4. There would be quite a number of conditions that may come up at one locality that would not be essential at others. Therefore, it would not be advisable to put any more conditions in the contract than would generally be used at various locations.

5. The laws of different states vary as to the granting clause, testimony clause, signatures, witnesses, seals and acknowledgments; also tax laws. In all cases the indenture should be modified to meet the requirements of the State law.

6. In cases where there are contracts with the Western Union or other companies, there should be a clause added to protect the interests of those companies operating under contract from the Railway.



PLAN



CROSS SECTION

No Scale

Appendix D

(4) FORM OF AGREEMENT FOR PIPE LINE CROSSINGS UNDER RAILWAY TRACKS

(5) FORM OF AGREEMENT FOR USE OF RAILWAY PROPERTY BY PIPE LINES PARALLELING RAILWAY, WITH SPECIAL REFERENCE TO PIPE LINES CARRYING HIGH PRESSURE INFLAMMABLE OILS AND GAS

A. A. Miller, Chairman, Sub-Committee; B. S. Dickerson, F. H. Fechtig, J. P. Hanley, A. C. Jackson, J. A. Russell.

Your Committee recommends the following form for adoption and inclusion in the Manual:

THIS AGREEMENT, made this ..... day of ....., 19...., by and between ....., hereinafter called the Railway Company, and ....., hereinafter called the Licensee,

WITNESSETH:

WHEREAS, the Licensee desires to construct, reconstruct, maintain and operate a ..... inch ..... pipe line for the handling of ....., under the tracks and/or upon the lands and property of the Railway Company, situated at or near ....., County of ....., State of ....., substantially as shown on Plan No. ....., dated ....., designated as ....., and the specifications hereto attached and made a part hereof,

It is mutually agreed as follows:

(1) The Railway Company grants permission to the Licensee to construct, reconstruct, maintain and operate said pipe line upon its lands and property and/or under its tracks in accordance with said plan and specifications hereto attached and forming a part hereof, subject to the conditions and requirements of this agreement.

(2) In consideration of this permit the Licensee shall pay to the Railway Company the sum of.....Dollars ($.....).

(3) The Licensee hereby acknowledges the title of the Railway Company in and to the premises described in this agreement and agrees never to assail nor resist said title.

(4) The Licensee agrees at its own cost, subject to the supervision and control of the Railway Company's Chief Engineer, or other designated officer, to lay and maintain the pipe line in such manner and of such material that it will not at any time be a source of danger to or interference with the safe operation of the railway. Arrangements must be made with the Chief Engineer or other designated representative of the Railway Company for the date and time for doing such work. Any work neglected by the Licensee or the contractor doing the work in connection with this laying or maintenance of the pipe line, or which the Railway Company would prefer to do itself, may be done by the Railway Company and the Licensee agrees to reimburse the Railway Company therefor.

(5) If any commission or other regulatory body duly constituted and appointed in compliance with Federal laws or the laws of the State in which the pipe line herein referred to is situated, shall by ruling or other general order prescribe a higher degree of protection than set forth herein or required under the attached specifications, then said ruling or general order shall be complied with for the pipe line referred to herein.

(6) The pipe, if used for conveying gas, natural or artificial oil, gasoline or other inflammable matter, matter under pressure or matter which from its nature may cause

damage, shall be laid and maintained when within ..... feet on each side of the nearest track inside an auxiliary or protecting pipe, and at a depth of not less than ..... feet below the base of rail where passing under the tracks, as set forth in the specifications. In the case of low pressure lines, modification of these requirements may be made with the approval of the Railway Company.

(7) If the Licensee desires or is required as herein provided to revise, renew, add to or alter in any manner the pipe line, or to increase its operating pressure or change the purpose for which the pipe line is used, it shall submit plans to the Railway Company and procure the approval thereof in writing before any work or increase of pressure or change of use in said pipe line is undertaken, and the terms and conditions of this Agreement shall apply thereto unless changed by mutual consent of the parties hereto.

(8) The Licensee agrees that in any future alteration of the alinement or grade of the Railway or the laying of additional tracks, the Licensee will bear the entire expense of changing said pipe line, to permit of said alterations of the alinement or grade of the railway, or the laying of additional tracks, so that the pipe line will continue to conform to the requirements of the Railway Company.

(9) The Licensee as part of the consideration for this permit hereby releases and waives any right to ask for or demand damages for or on account of loss or damage to the pipe line and contents thereof, whether attributable to the fault, failure or negligence of the Railway Company or otherwise.

(10) The Licensee shall indemnify, protect and save harmless the Railway Company from and against all claims, suits, costs, charges, causes of action, or damages made upon or incurred by the Railway Company in connection with this license.

(11) This permit is given and accepted upon the express condition that the same may be terminated at any time by either party by serving not less than ..... days' notice in writing upon the other party (stating therein the date when such termination shall become effective), and that, upon such termination the Licensee shall abandon the use of the pipe line laid in pursuance hereof and, if required by the Railway Company, remove the same and under the direction of the Railway Company restore the premises of the Railway Company occupied thereby to a condition substantially equal to the condition of said premises prior to the laying of said pipe line therein.

(12) In case the Licensee shall fail to remove its property or to restore the premises as aforesaid within ..... of said termination, the Railway Company may proceed with such work at the expense of the Licensee.

(13) No termination of this agreement shall release the Licensee from any liability or obligation which may have attached or accrued prior to ..... such termination, or under the provisions hereof relating to the duties of the Licensee after the service of notice of termination as herein provided.

(14) This agreement shall inure to the benefit of and be binding upon the legal representatives and successors of the parties hereto, but no assignment hereof by the Licensee, its legal representatives and successors, shall be binding upon the Railway Company without the written consent of the Railway Company in each instance.

In Witness Whereof, the parties hereto have executed this agreement in..... ..... the day and year first above written.

Witness: .....

..... By .....

Witness: .....

..... By .....

Appendix E

(6) FORM OF AGREEMENT WITH PUBLIC AUTHORITIES FOR HIGHWAY GRADE CROSSING ELIMINATION OR SEPARATION

J. S. Lillie, Chairman, Sub-Committee; E. H. Barnhart, B. Herman, C. B. Niehaus, Charles Silliman, W. R. Swatosh.

This subject has been in Committee two years. Last year we collected existing agreements from a number of railroads, covering elimination or separation of grade crossings in different states and Canada. These were carefully studied and a form prepared which has been revised some four or five times. Committee IX—Grade Crossings, has furnished suggestions with regard to this form of agreement.

It is recommended that this form of agreement be accepted and printed in the Proceedings as information and for discussion, and that the subject be continued.

FORM OF AGREEMENT WITH PUBLIC AUTHORITIES FOR HIGHWAY GRADE CROSSING ELIMINATION OR SEPARATION

THIS AGREEMENT, made this ..... day of ..... 19...., by and between the ..... Company, a corporation organized and existing under the laws of the State of ....., hereinafter called the "Railway Company", and the ....., acting through its ....., hereinafter called the ....

WITNESSETH:

WHEREAS, it is desired to eliminate the grade crossing known and designated as ....., a public highway in the County of....., State of ....., crossing the ..... tracks of the Railway Company at grade in the ..... of ....., County of ..... and State of ....., a distance of ..... feet ..... of the Railway Company's Mile Post ..... from .....; by separating the grades and a plan marked Exhibit A, a profile marked Exhibit B and specifications marked Exhibit C have been prepared, approved and accepted by both parties hereto as the manner of doing the proposed work, each sheet of the exhibits being identified by the signatures of the approving officers.

NOW, THEREFORE, in consideration of the covenants and agreements herein contained, it is mutually agreed as follows:

1. The grades of the public highway and the tracks of the Railway Company shall be separated and the ..... shall be carried over the ..... on a structure in accordance with the plan marked Exhibit A, profile marked Exhibit B, and the specifications marked Exhibit C, attached hereto, hereby approved and made a part of this agreement. Detail plans, including methods of performing the work and specifications for the materials to be used, amplifying Exhibits A, B and C, shall be prepared by the ..... and approved by the ..... before letting of any contract, purchase of any material or the performance of any work. Failure of the ..... to approve or notify the ..... of its objections to plans and/or specifications within ..... days after receipt will constitute approval by the .....

2. Subject to requirements deemed by it necessary for the safety of its traffic and the protection of its property, the Railway Company grants to the ..... the right to enter upon the following described premises and right-of-way of the Railway Company, ... for the purpose of constructing, maintaining and/or reconstructing the structure shown on Exhibit A.

3. The Railway Company shall furnish all material, supplies and equipment for and by contract or with its own forces or a combination of both do and perform all the work of construction of the ..... and all other work appurtenant thereto or in connection therewith. (Division of work to be specified for each grade separation project) The ..... shall by its contractor or contractors, with its own forces or a combination of both, do and perform all other work of construction of the ..... and all work appurtenant thereto or in connection therewith, except as herein otherwise provided. All work shall conform to and comply with the terms of this agreement and the exhibits attached hereto.

4. The Railway Company shall, if it so elects, do any part or all of the construction work or changes of any character, affecting its tracks, including temporary structures under its tracks, detour tracks to facilitate construction, roadbed or the drainage of its right of way and/or lands necessary under this agreement. The Railway Company shall make all changes in its signals, telephone and telegraph lines and other similar facilities and/or change or cause to be changed telephone or telegraph lines of its licensees over which it has control, adjacent to and made necessary by the work provided for in this agreement. It is understood and agreed that all construction work and changes provided for in this section, except where the Railway Company licensees are required to make the necessary changes at their expense, are part of the work necessary for grade separation under this agreement and shall be included in the total cost and apportionment thereof.

The Railway Company shall, when, and if necessary in its opinion, provide watchmen and/or flagmen, to protect its property and the movement of its trains during construction. The expense thereof shall be paid by the Railway Company and shall be included in the total cost of the grade separation and the apportionment thereof.

5. Each party hereto shall keep accurate records of the work performed by its own forces. The cost of all materials and supplies so far as practicable shall be the cost f.o.b. the site of the work, including revenue freight. Where materials and supplies are furnished from the stocks of the Railway Company there shall be added to the storehouse price to cover the cost of supervision, inspection, transportation and accounting, ... per cent (.....%). To the cost of labor of the Railway Company's forces there shall be added ..... per cent (.....%) to cover supervision, accounting and use of small tools. To the cost of the Railway Company labor shall be added Employer's Liability and Public Liability insurance costs. Equipment shall be charged to the work at the customary established rental rates of the Railway Company. No percentages shall be added to any work let by contract, provided, that on any work let by contract, the item of workmen's compensation and public liability insurance shall be carried by the Contractor and included as a specific item of cost.

As each party hereto proceeds with the work it is required to do, it shall prepare monthly estimates of the cost and expense of such work and an adjustment shall be made between the parties each month; such bills shall be due and payable at the office of their respective Treasurers on or before the ..... day of the following month.

6. The factors included in the cost and the division thereof between the parties hereto shall be as follows: .....
.....
.....

7. It is agreed ..... will, in letting any contract or contracts, require that the contractor, or contractors, shall furnish and deliver to the..... .....a good and sufficient surety bond in a company licensed to do business in ..... for the faithful performance of all his obligations under the contract or contracts let, and which bond shall also protect, indemnify and save harmless the Railway Company and the ..... from and against and insure the payment by the contractor of any and all loss or damage or injury which they, or either of them, may sustain through injury to or death of any person or persons, loss of or damage to property of any person, firm or private or municipal corporation; and to protect, indemnify and save harmless the Railway Company and the ....., or either of them, from and against any and all claims, demands, suits and causes of action, judgments, costs, attorneys fees, and other expenses growing out of or resulting from any act of omission or commission or from a breach of the obligations of the contractor, his agents, servants or employes, in or incident to the construction of the ..... and/or the work attendant thereupon, any maintenance or repairs in connection therewith, and/or failure to comply with any of the requirements or obligations of this agreement.

The penal sum of the bond, if there be but one contract and bond, or the total of the penal sums of all such bonds, if there be more than one contract and bond, shall be ..... Dollars ($.....). Each bond shall be subject to the approval of both parties to this agreement. The ..... shall cause the contractors to submit the bond or bonds to the ..... for approval before the execution thereof and the ..... shall, within ..... (.....) days after receipt thereof, notify the ..... and the contractor of its approval or disapproval of the bond or bonds. If the ..... shall disapprove the execution of the bond or bonds, it shall specify its reasons therefor.

8. Before beginning the work of construction on the Railway Company's property the ..... shall notify the Chief Engineer of the Railway Company in writing, of the date at least ..... (.....) days in advance of the date on which it is desired to start any work.

9. No waste excavation shall be deposited on the property of the Railway Company except with and under the written instructions of its ..... first had and obtained.

10. In the performance of said work no construction material or equipment shall be stored or placed by the ..... or its contractor upon the Railway Company's property except under the written authority and supervision of the Railway Company's ..... and then so as to not interfere with the operation or maintenance of the Railway Company's trains, roadbed, and/or tracks.

11. A minimum vertical clearance of ..... feet (.....') ..... inches (.....") over the top of the rail and a horizontal clearance of ..... feet (.....') ..... inches (.....") measured from the center line of the nearest track shall be maintained at all times during the construction. The clearance of the permanent structure shall conform to that shown on Exhibit A and shall conform to all Municipal Ordinances and State Laws and rules of other governmental bodies.

12. The ..... and its contractor or contractors shall comply with the rules and regulations of the Railway Company or the instructions of its representative in relation to the proper manner of protecting the tracks and property of the Railway Company and the traffic moving on such tracks, as well as wires, signals and other property of the Railway Company, its tenants or licensees at and in the vicinity of the work during the period of construction.

13. All water pipes, services or other underground conduits belonging to or controlled by the parties hereto and affected by the improvement herein provided for shall be taken care of so that they will function properly at all times during the construction of the improvement and the cost of caring for and of relaying or changing such facilities shall be considered a part of the cost of the grade separation work and included in the total cost and apportionment thereof.

All municipal or private corporations or individuals owning or maintaining wires, poles, pipes, conduits or other equipment or appliances, structures, or sub-structures for furnishing water, gas, telephone, telegraph, or electric service, or for transportation or for any other purpose, in the highway or on the property now owned or to be owned by the State and any municipality thereof, within the limits herein provided for or affected by construction of the ..... under this agreement, shall be required by the ..... to the extent of the exercise of its lawful powers, to change, relocate, or remove as may be, at their cost and expense, in such manner and to such extent as may be necessary to permit the changes and work herein contemplated and to support and keep the same in repair and operation during the progress of such work, upon notice from the .....

If, during construction any detours or temporary roads are necessary, the ..... shall arrange therefor and the cost thereof shall be borne by the .....

14. The ..... shall construct and maintain at its expense, a good and sufficient fence or guard, approved by the Railway Company, along the shoulder of the embankments on each side of the bridge, extending from the foot of the embankment to and connecting with the structure. Such fence or guard shall be of sufficient strength to prevent vehicles running off the approaches onto the tracks or property of the Railway Company.

15. The ..... or their duly authorized representative shall at all times construct, reconstruct, operate and maintain without cost or expense to the Railway Company any and all lights, signs (including highway symbols), signals and protection devices, necessary for the operation of, or required by law or order of any public body or commission having jurisdiction of or in connection with, the ..... road, structure, connecting highways, or any part of them, except that any bridge warning signals necessary along the Railway Company's tracks shall be installed and maintained by the Railway Company at its cost and expense.

16. The Railway Company shall have the right, subject to the reasonable supervision of the ..... without any charge to the Railway Company, to attach to the structure after its completion, at any time and from time to time, and to operate and maintain at the expense of the Railway Company, signals, signal posts or supports, telegraph, telephone or other wires, pipes and conduits and devices of whatever kind, nature and description that may now or hereafter be convenient or necessary in the operation of the railway.

17. The Railway Company shall have the right, subject to the reasonable supervision of the ....., without any charge and at the expense of the

Railway Company, to construct and use at any time and from time to time, driveways or roadways connecting the property of the Railway Company with said structure or its approaches.

18. The structure shall be maintained in accordance with this agreement, the exhibits attached hereto and detail plans and specifications provided for herein and any alterations or changes in that part of the structure on or over the property of the Railway Company shall be subject to the prior approval of the Railway Company in writing and shall be made at the sole cost and expense of the .....

Upon completion of the structure and all other work provided for in this agreement, the ..... shall, at its own cost and expense, maintain and repair ..... (including drainage necessary in connection with the approaches to the structure and the highway in the vicinity of the same), and the Railway Company shall, at its own cost and expense, maintain and repair .... Provided that plans and specifications for all changes in maintenance or repairs made by either party or its contractors shall be submitted to the other party for approval and the party to whom such plans and specifications are submitted shall notify the other party within ..... (.....) days after receipt of such plans and specifications of its approval or disapproval. All maintenance of and repairs to the structure shall be so conducted as not to interfere with the operation of the Railway Company's tracks, trains, and/or property or that of its tenants.

19. In the event either of the parties hereto shall find it necessary after construction that the structure be altered, the work thereof shall be done as hereinabove provided for the original construction, each party to bear that part of the cost of such work as is done at its request and for its benefit except that where any changes are made, including strengthening for the purpose of carrying added loading, due to bus, truck and/or street car traffic, the Railway Company shall not be required to pay any part of such cost.

20. Rates being equal or better, the ..... shall give or cause to be given preference to the Railway Company's lines in the routing of all materials and supplies required in connection with the construction of the ..... To this end the Railway Company shall have the opportunity of approving the routing of all materials and supplies before shipment is started.

21. The structure and approaches thereto shall hereafter be held and considered as a public highway of the state and shall not be subject to taxation. The Railway Company shall not be liable for any special assessment levied against its property for or on account of said grade separation, its maintenance or repairs, nor on account of any highway widening or other improvement on or along said road known as ..... road.

For the purposes of this agreement it is hereby agreed by and between the parties hereto that the Railway Company is the owner of that part of the grade separation described as follows: ..... and that the ..... is the owner of all other parts of the entire grade separation project.

22. The ..... agrees to close or have closed to all traffic of every character, and permanently abandon, or have permanently abandoned as a public highway, the present road or highway crossings now in use and located at .... and ..... The ..... also agrees not to open or permit to be opened, insofar as it can legally prevent the same, any public road or highway of any character across the tracks or right of way of the Railway Company within a distance of ..... of the structure

provided for in this agreement, without the consent of the Railway Company first had and obtained.

23. This agreement shall inure to the benefit of and be binding upon the parties hereto, their successors and assigns.

In Witness Whereof, the parties hereto have caused this agreement to be signed ..... by their duly authorized officers, duly attested and their respective corporate seals to be hereunto affixed, the day and year first above written.

Attest: ..... Railway Company

..... By .....
Secretary President

Witnesses: .....

..... By .....

....

REPORT OF COMMITTEE X—SIGNALS AND INTERLOCKING

P. M. Gault, *Chairman;*
F. H. Bagley,
G. H. Dryden,
W. J. Eck,
W. H. Elliott,
J. V. Hanna,
C. R. Hodgdon,
C. A. Mitchell,
J. C. Mock,
R. D. Moore,
H. G. Morgan,
H. H. Orr,
J. A. Peabody,
F. W. Pfleging,
W. M. Post,
A. H. Rudd,
C. H. Tillett, *Vice-Chairman;*
Leroy Wyant,
T. S. Stevens,
E. G. Stradling,
C. A. Taylor,
W. M. Vandersluis,
F. B. Wiegand,
Leroy Wyant,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully presents herewith report covering the following subjects:

2. Report developments of automatic train control, collaborating with Train Control Committee, A.R.A. (Appendix A).

3. Developments of automatic highway crossing protection, collaborating with Committee IX—Grade Crossings. A designated member of your Committee has collaborated as requested.

4. Increased efficiency secured in operation by signal indication, including remote control of switches, and centralized traffic control, in lieu of train orders and timetable superiorities, collaborating with Committee XXI—Economics of Railway Operation (Appendix B).

5. Synopsis of the principal current activities of the Signal Section, A.R.A., supplemented with list and references by number of adopted specifications, design and principles of Railway Operation (Appendix C).

6. Furnish the Special Committee on Clearances the information required by it pertaining to signals and interlocking. A designated member of your Committee has collaborated as requested.

Action Recommended

2. That Appendix A be received as information.
4. That Appendix B be received as information.
5. That Appendix C be received as information.

Respectfully submitted,

The Committee on Signals and Interlocking,
P. M. Gault, *Chairman.*

Appendix A

(2) DEVELOPMENTS OF AUTOMATIC TRAIN CONTROL

W. J. Eck, Chairman, Sub-Committee; W. H. Elliott, F. W. Pfleging.

AUTOMATIC TRAIN CONTROL

Since the last report, as printed in the Advance Notice for the May, 1933, meeting, the following roads have filed petitions with the Interstate Commerce Commission for modification of the train control orders, with the following results as of October 18, 1933:

To discontinue operation of automatic train control:

Chicago, Indianapolis & Louisville	Granted
St. Louis–San Francisco	"
Boston & Maine	Denied
Chicago, Milwaukee, St. Paul & Pacific	"
Baltimore & Ohio	"
Norfolk & Western	"
Alton	Pending
Southern Pacific	"

To discontinue operation of automatic train control and operate by cab signals in conjunction with wayside signals:

Norfolk & Western	Granted
Delaware, Lackawanna & Western	"
Pennsylvania	"
Reading	"
Central Railroad of New Jersey	"
Long Island	"
Boston & Maine	Pending

The three decisions now pending involve the following conditions:

Southern Pacific to discontinue operation of nearly three-fourths of its mileage; Alton to discontinue operation of its entire installation; and Boston & Maine to dispense with the brake applying apparatus and operate by cab signal indicator and wayside signals.

In all cases where petitions were granted approval was given "until further order of the Commission"; also the installations changing to cab signals were subject to inspection and approval.

The operation of a total of 1738 track miles of automatic train control, not including the Alton and Southern Pacific, has been discontinued by Interstate Commerce Commission authority, involving a reduction of 640 locomotives and 10 motor cars from the total equipped. Installations changed from train control to cab signals total 3155 track miles, not including the Boston & Maine, involving 1876 locomotives and 295 motor cars of the total originally equipped with automatic train control.

The Committee on Automatic Train Control has continued its studies on interchangeability but has, due to general economic conditions and on account of the fact that certain types of devices are being eliminated from present consideration, refrained from initiating further field tests and experiments along these lines. It still considers that the subject is worthy of consideration and the attention of the members is called to the remarks of S. N. Mills, Assistant Director of the Bureau of Safety, Interstate Commerce Commission, before the last annual meeting where he stated "that interchangeable operation should be provided for wherever practicable in changing over from train control to cab signal operation and should certainly be provided for in any future installations of automatic cab signal devices".

The Committee on Automatic Train Control has prepared and approved a set (Exhibit A) of proposed standard aspects and indications for continuous automatic cab signals. These proposed standards are in accord with the A.R.A. Standard Code, and are to be presented to other interested sections and divisions of the American Railway Association for approval as standard practice. This work was undertaken at the suggestion of the Bureau of Safety. On Exhibit B are shown the specifications and requirements for continuous automatic cab signal system as prescribed by the Interstate

Commerce Commission in the case of the following railroads, all of which have wayside signals:

Norfolk & Western
Delaware, Lackawanna & Western
Pennsylvania
Reading
Central Railroad of New Jersey
Long Island

The Committee on Automatic Train Control and the Bureau of Safety are continuing to co-operate in investigations that appear desirable, in order that information may be secured with respect to irregular functioning of apparatus. A recent investigation of the effect of continuous receivers coming in contact with safety hangers or chains, or being loose on supports, and the effect on proper operation, has been completed. These experiments involved both laboratory roadway, and roundhouse work, and interesting data and conclusions were reached.

Appendix B

(4) INCREASED EFFICIENCY SECURED IN OPERATION BY SIGNAL INDICATION, INCLUDING REMOTE CONTROL OF SWITCHES, AND CENTRALIZED TRAFFIC CONTROL, IN LIEU OF TRAIN ORDERS AND TIMETABLE SUPERIORITIES

W. M. Post, Chairman; W. J. Eck, P. M. Gault, W. M. Vandersluis, G. H. Dryden, C. A. Mitchell.

Committee X has presented several reports showing the savings and increased efficiency secured in railway operation by signal indications in lieu of train orders and timetable superiorities. The Committee presented reports in 1932 and 1933 on the economic results of centralized traffic control installations. In addition to definite money savings due to block and interlocking stations discontinued, and gross ton miles per train hour increased, there is an increase in the margin of safe operation, which results in intangible savings which cannot be definitely determined, but which are nevertheless real.

This report relates to intangible benefits and savings difficult to determine accurately provided by a Centralized Traffic Control installation.

A CENTRALIZED TRAFFIC CONTROL SYSTEM

1. Reduces number of written train orders. Prior to installation of Centralized Traffic Control on the New York Central Lines between Berwick and Stanley (40 miles of single, 3 miles of double track), an average of 90—"31" orders and 3600—"19" orders per month were issued. Since the Centralized Traffic Control installation in 1927, no written train orders have been issued for execution in the Centralized Traffic Control section. Orders are conveyed by signal indication at the time and place they are to be executed. Special instructions are transmitted to trainmen by telephone.

2. Reduces errors in the transmission of orders. Orders are transmitted by signals, which are surrounded by mechanical and electrical safeguards. If the control operator displays a signal not intended, protection against conflicting movements is automatically provided.

3. Eliminates possibility of errors in interpretation or execution of written orders.

4. Eliminates delays due to waiting for written train orders.

5. Provides complete information constantly available concerning train movements. Lights on the machine indicate position of switches and signals and occupancy of track at passing siding switches, and, in many cases, in blocks between passing sidings. Train graph provides a record of time of trains between passing points.

6. Provides means so that disregard of stop signal indication can be instantly detected by the control operator. The knowledge that the control operator can by observing the lights on the machine detect any disregard of a Stop signal tends to keep the engineman alert and thus reduces the chance that signals will be passed when displaying Stop.

7. Saves stops or reduction in speed for delivery of train orders.

8. Provides facilities for non-stop meets at passing sidings.

9. Eliminates stops due to necessity for train crews to operate hand-thrown switches.

10. Decreases damage to equipment and lading caused by stopping and starting trains.

11. Decreases personal injuries caused by stopping and starting trains.

12. Provides immediate information as to whether or not trains are losing time, and control operator is better able to plan the meets at passing sidings.

13. Facilitates meets on close schedule and reduces time for clearing main line for superior trains.

14. Provides means for checking speed of trains between stations and delay at stations.

15. Provides facilities for handling peak traffic conditions with no loss of efficiency.

16. Provides greater protection for the movement of motor cars and other equipment of the Maintenance of Way Department and control operator can protect their movements by signals when conditions require.

17. Eliminates possibility of throwing switches immediately ahead of an approaching train, as switches are equipped with approach locking.

18. Provides signals for train movements entering and leaving sidings.

19. Provides facilities for stopping, holding or re-routing trains, which control operator may use when necessary.

20. Tends to reduce the number of locomotives required and per diem charges.

21. Increases good-will on account of decreased time of goods in transit.

22. Increases average speed in miles per hour over the territory.

Appendix C

(5) SYNOPSIS OF THE PRINCIPAL CURRENT ACTIVITIES OF THE SIGNAL SECTION, A. R. A., SUPPLEMENTED WITH LIST AND REFERENCES BY NUMBER OF ADOPTED SPECIFICATIONS, DESIGNS AND PRINCIPLES OF SIGNALING PRACTICE

E. G. Stradling, Chairman, Sub-Committee; H. H. Orr, Leroy Wyant.

CURRENT ACTIVITIES OF THE SIGNAL SECTION A.R.A.

Since March, 1933
(As of November, 1933)

1. Revised Regulations for Membership in the Signal Section of the A.R.A.
2. Continued the work of standardization of colored glasses, receiving the co-

operation and help of the Corning Glass Works and the Bureau of Standards, Colorimetry Section, at Washington.

3. Continued the study of reflecting devices as a substitute for oil or electric lights.

4. Making a study of the shunting of A C track circuits by rubber tired oil-electric passenger cars.

5. Kept in touch with those roads using automatic train control. Compiling information as to present day practices.

6. Decided upon a conclusion on Economical Train Performance on Single Track.

7. Prepared new requisite for Signal Protection for Spring Switches.

8. Prepared and recommended a Design for Spring Switch Marker.

9. Prepared and recommended a Design for Grade Signal Marker.

10. Adopted A.R.E.A. forms for Construction Contract, Proposal and Bond.

11. Prepared an Example showing Use of Unit Value Basis in connection with interlocking plants.

12. Revised Forms for Wire Inspection Report.

13. Prepared instructions for Maintenance and Operation of Direct Current Track Circuits.

14. Prepared definitions for technical terms:

Chromatic Aberration.
Centralized Traffic Control.
Dual Control.
Drawbridge.
Reflector Unit.
Double Refraction Reflector.
Single Refraction Reflector.

SPECIFICATIONS REVISED

	Old No.	*New No.*
Plug Type Rail Bonds and Track Circuit Connectors	15131	15133
Portable Direct Current Volt-Ammeter RSA	1378 &) 8519)	8533
Switchboards	10720	10733
Electric Motor Semaphore Signal	2029 &) 7919)	7933
Fuses	9630 (7a)	9633
Electro-Mechanical Interlocking Machine	12526) 13226) 13430)	13433
Electro-Pneumatic Interlocking	6725	6733
Double-Braided, Weatherproof Thirty Percent Conductivity Copper-Covered Steel Line Wire	7131	7133
Mineral Matter Rubber Compound Insulated Signal Wire	11132) Sec. 15 & 20)	11133
Wire Joints	11020	11033
Aerial Braided Cable	8932 (5a)	8933

DRAWINGS REVISED

	Old No.	*New No.*
Plug Type Rail Bond	1631–A	1631–B
Track Circuit Connector	1632–A	1632–B
Methods of Measuring Ground Resistance	1377	1377–B
Insulated Wire Joint	1406	1406–B
Hand Lantern Globes	1611–B	1611–C

REQUISITES REVISED

The Mechanically Interlocking of the Levers of Interlocking Machines.

NEW SPECIFICATIONS

Reflector Units	No. 15633
Railroad Highway Grade Crossing Signs	No. 15533

NEW DRAWINGS

	No.
90 Degree Cast Iron Crossing Sign	1640–A
Adapter Clamp for Crossing Sign	1641–A
90 Degree Reflector Crossing Sign Assemblies	1642–A
90 Degree Reflector Crossing Sign Details	1643–A
Cast Iron Track Sign	1644–A
Reflector Track Sign	1645–A
Reflector Stop on Red Signal Sign	1646–A
Adapter Clamp and Details for Signs	1647–A
Reflector Stop When Swinging Sign	1648–A
Reflector Crossing Signal Marker	1649–A
Details of Numerals for Track Signs	1650–A

DRAWINGS TO BE REMOVED FROM THE MANUAL

		No.
Zinc for Gravity Battery	RSA	1087
Coppers for Gravity Battery	RSA	1088
Indication Locking Circuits	RSA	1173
Line Charging Panels	RSA	1174
Circuits for Line Charging Panels	RSA	1420
Relay Box Size A and B		1182
Relay Box Details Size B		1183
Relay Box Details Size A		1184
Cable Post and Relay Box Assembly		1185
Storage Battery, Jars, Covers, Hold-downs and Sand Trays		1224–B
Storage Battery Lead Elements		1241–B
Storage Battery Connection Bolts		1340
Storage Battery Separator		1341–B
Portable Storage Battery Lead Type		1248
Cartridge Enclosed Fuses		1309
Highway Crossing Signal Flashing Light		1546–A
Highway Crossing Signal, Wig-wag		1547–A

SPECIFICATIONS TO BE REMOVED FROM MANUAL

Gravity Battery Coppers	3328
Gravity Battery Zincs	3428
Copper Sulphate	5028

REQUISITES TO BE REMOVED FROM MANUAL

For Lightning Arresters for Signals.

RECOMMENDATIONS TO BE REMOVED FROM MANUAL

Table of Resistances for D.C. Relays.

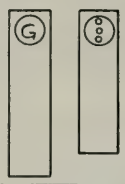
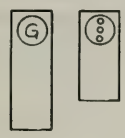
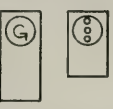
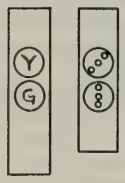
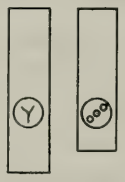
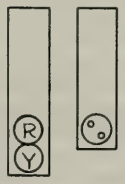
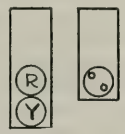
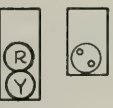
Recommendations and Drawings for Signs or Markers for Conveying Instructions to Engineers.

FORMS TO BE REMOVED FROM MANUAL

Forms for Recording Signal Performance.

"EXHIBIT A"

PROPOSED STANDARD ASPECTS AND INDICATIONS FOR CONTINUOUS AUTOMATIC CAB SIGNALS.

NAME	INDICATION	ASPECT		
		4-Indication	3-Indication	2-Indication
Clear	Proceed (Code Rule 281)			
Approach Medium	Approach next signal, (or indication point) at not exceeding medium speed. (Code Rule 282.)			
Approach	Prepare to stop at next signal, (or indication point) Train exceeding medium speed must at once reduce to that speed. (Code Rule 285)			
Restricting	Proceed at restricted speed. (Code Rule 290)			

American Railway Association
Comm. on Automatic Train Control
May 3, 1933.

G - Green
Y - Yellow
R - Red.

Exhibit B

INTERSTATE COMMERCE COMMISSION

Specifications and Requirements for Continuous Automatic Cab-Signal System

Definitions

For purposes of these specifications, the following definitions will apply:

Automatic Cab-Signal System.—A system which provides for the automatic operation of the following:

(a) Cab signal—a device located in the cab which, when locomotive and roadway apparatus are in operative relation, displays indications of conditions in advance.

(b) Cab indicator—a device located in the cab which indicates a condition or a change of condition of one or more elements of the system.

Block.—A length of track of defined limits, the use of which by trains is governed by fixed signals or cab signals or both.

Cabs.—The compartment occupied by engineman, fireman or motorman, of the engine, motor car or multiple-unit car from which the propelling power of the train is controlled.

Continuous Control.—A type of control in which the locomotive apparatus is constantly in operative relation with the track elements and is immediately responsible to a change of conditions in the controlling section which affect train movement.

Controlling Section.—A length of track of one or more track circuit sections by which the track elements governing approach to, or movement within, a block are controlled.

Locomotive.—A self-propelled unit of equipment used in train service.

Track Element.—That portion of the roadway apparatus to which the locomotive apparatus is directly responsive.

Specifications

1. The purpose of these specifications is to prescribe essential features involved in the design, construction, installation, operation and maintenance of automatic cab-signal systems of the continuously controlled type, without automatic train control.

2. The automatic cab-signal system shall function to display a cab-signal indication which constantly corresponds with conditions in advance in the controlling section.

3. The automatic cab-signal system shall be so arranged that a change of conditions affecting train movement which occurs within braking distance in advance will result immediately, regardless of the location of the locomotive in the controlling section, in a change of cab-signal indication corresponding with these changed conditions.

4. The automatic cab-signal system shall be so arranged that when a locomotive enters and is within a block in which there exists a condition causing a restrictive indication the cab signal will display the most restrictive indication required by that condition.

5. The automatic cab-signal system shall be so arranged that when the cab signal changes to display a more restrictive indication an audible cab indicator will sound and continue to sound until acknowledged.

6. The automatic cab-signal system shall be so interconnected with the fixed-signal system that the cab signal will display indications consistent with the indications of the fixed signals, except when a fixed signal displays a less restrictive indication than is required or warranted by existing conditions.

7. The cab signals shall be plainly visible to members of the locomotive crew when they are in their accustomed stations in the cab.

8. The cab indicator shall have a distinctive sound which will be clearly audible to members of the locomotive crew under all operating conditions when they are in their accustomed stations in the cab.

9. The automatic cab-signal system shall be so constructed that the cab signal will, so far as practicable, display its most restrictive indication if an essential part fails or is removed, or a break, cross or ground occurs in electric circuits, or in case of a failure of energy.

10. The apparatus shall be so constructed that proper operative relation between the parts along the roadway and the parts on the locomotive will be assured under all conditions of speed, weather, wear, oscillation and shock.

11. The apparatus shall be so constructed as not to interfere with the application of the brakes by operation of the engineman's brake valve or to impair the efficiency of the air-brake system.

12. The apparatus shall be so constructed that it may be applied so as to be operative when the locomotive is running forward or backward.

13. The apparatus shall be so constructed that it will operate under all weather conditions which permit train movements.

14. The apparatus shall be so constructed as to conform to established clearances for equipment and structures.

15. The apparatus shall be so constructed and installed that it will not constitute a source of danger to trainmen, other employees, or passengers.

16. The apparatus shall be so constructed, installed and maintained as to be safe and suitable for service. The quality of materials and workmanship shall conform to this requirement.

A

REPORT OF COMMITTEE XVIII—ELECTRICITY

W. M. Vandersluis, *Chairman;*
H. M. Bassett,
D. J. Brumley,
H. A. Currie,
J. H. Davis,
J. S. Hagan,
Paul Lebenbaum,
W. L. Morse,
R. J. Needham,
E. H. Olson,
A. E. Owen,
J. A. Peabody,
J. V. B. Duer, *Vice-Chairman;*
H. W. Pinkerton,
J. M. Trissal,
R. P. Winton,
Sidney Withington,
G. I. Wright,
Committee.

To the American Railway Engineering Association:

Your Committee has been instructed to (1) Keep the Association informed of developments in the application of electricity to railway service, and (2) present a synopsis of the current activities of the Electrical Section, supplemented with list and reference by number of adopted specifications, designs and principles of practice.

Reference is made to the series of reports made by committees of the Electrical Section, reprinted in full in Bulletin 359, for September, 1933.

No session of the Electrical Section was held in 1933, therefore no action has been taken on the reports submitted.

A condensed summary of these reports is given below.

SUMMARY OF REPORTS

1. Developments in Application of Electricity to Railway Service

A useful bibliography of articles appearing in a selected list of periodicals covering period January, 1932 to June, 1933, forms basis of report.

2. Inductive Co-ordination

Report is made on the issuance of a set of "Principles and Practices for the Inductive Co-ordination of Railway Electrical Supply Facilities and the Communication Facilities of the Bell Telephone System." Cooperative work with the Edison Electric Institute on "Principles and Practices for the Inductive Co-ordination of the Wire Systems of Railways and Central Station Companies" is continuing and is partially completed. A statement is presented regarding co-ordination measures employed on the Chicago, Milwaukee, St. Paul & Pacific Railroad electrification. The report also contains a review of article appearing in the "Oerlikon Bulletins," regarding the impedance of the overhead line and return conductors of single-phase railways, and what influence the current return path has on it.

3. Power Supply

Reference is made as to the general progress of electrical power supply in the United States, and to a limited extent in other parts of the world, to articles appearing in "Power" January, 1933, and to "Electrical World," May, 1933. In connection with railway electrification developments in the United States, the large Pennsylvania Railroad program is by far the most important. Reference is made to a description of this extensive project by J. V. B. Duer, on "Power Supply for the Pennsylvania Railroad," presented before the A. I. E. E., January, 1933. Railway electrification developments in Sweden and France are reported on. The position of electric power supply in the United

States for 1932 is summarized. Report is also made on servicing equipment along right-of-way for air-conditioning and pre-cooling of cars. The procedure followed and the equipment used on a number of roads is listed.

4. Electrolysis

Report is made on the elimination of the effects of electrolysis by the use of non-metallic sheathed cables. In view of the fact that considerable development may be expected within the next few years of the use of non-metallic sheathed cables for the mitigation of the effects of electrolysis, this study will be continued.

5. Co-operation in Miscellaneous Regulations

Progress is reported on this assignment.

6. Overhead Transmission Line and Catenary Construction

Progress report only. Consideration is being given to a proposal to modify existing specifications for bronze trolley wire so as to include a high conductivity wire under the auspices of a joint committee, composed of representatives of the Electrical Section, American Society for Testing Materials and American Transit Association.

7. Standardization of Apparatus and Materials

Progress is reported on revision of Specifications for Friction Tape, Rubber Insulating Tape, and for Porcelain Insulators. Recommendation is made that individual members review the list of ASA standards with the view of applying such approved specifications on their individual railroads, and the consequent savings accruing from such general use are pointed out.

8. Electric Heating

The report deals with (1) application of heat for various purposes; (a) electric snow melters; (b) water heaters and space heating; and (c) miscellaneous electric heating; (2) electric welding and equipment (as applied to maintenance of way work). As these subjects are relatively new to the Electrical Section, their development in railway work will be followed closely.

9. Application of Motors

The report deals with the application of different types of motors, both standard and special, for uses other than rolling stock. The report is divided into (a) alternating current motors; (b) direct current motors; (c) special equipment; (d) standardization, and (e) application of proper motors.

10. Clearances for Third-Rail and Overhead Working Conductors

A series of tables are presented indicating the present-day practices on electrified roads covering Third-Rail and Overhead Conductor Clearances and mileage in operation as of October 1, 1933. Progress is also reported on revision of the clearance lines for equipment and permanent way structures adjacent to third-rail and third-rail structures.

11. Protection of Railroad Equipment from Danger of Fire Caused by Elec- Sparks During the Transfer of Inflammable Liquids

The report consists of a revision of the current rules for the protection of oil sidings, covering a change in the wording of the title for greater clarity; Section A amplified for reasons of clarity; Section C–1 added to simplify the protective measures and a saving

in the expense where there is no danger from stray earth currents; Section C–2 enlarged to provide against bridging of insulated rail joints; Section C–3 added to provide protection from flashes from trolley wires or third-rails; Section C–5 added as a precaution against high resistance; Section D omitted as unnecessary. Recommendation is made that the revised rules be submitted to the Mechanical and Motor Transport Divisions, the Association of Railway Electrical Engineers and the American Petroleum Institute for comment.

12. Specifications for Track and Third-Rail Bonds

Progress is reported on this assignment, with recommendation that it be continued.

13. Illumination

Minor changes in the lamp schedules are proposed. Report contains developments in incandescent lamps—(a) general purposes lighting; (b) new lamp and lighting developments for special purposes; (c) locomotive and train lighting lamps; (d) lamp tests and rejections. Report is also made on floodlighting in railroad yards.

14. Design of Indoor and Outdoor Substations

The report deals with (1) AC protection of substations (a continuation of last year's report); (2) insulation coordination; (3) high-speed trolley circuit breaker performance; (4) new apparatus developments.

15. High Tension Cables

Report cites the installation across the East River, New York, of 14 cables, and of an installation of 15 cables at Wallabout Bay, New York. Reference is also made of one installation of a large section single-conductor cable at 69 k.v., in which the copper section was made up of several lightly insulated sections in the effort to reduce skin effects.

16. Application of Corrosion-Resisting Materials to Railroad Electrical Construction

Progress is reported on the results of observations of samples installed at New Haven, Conn., and at Hemphill Tunnel on the Norfolk & Western, and also at Lambert's Point pier.

17. Form of Power Contract for Large Blocks of Power

Progress is reported on this assignment.

18. Radio Antennae on Cars in Electrified Territory

Progress is reported on this assignment.

Action Recommended

That the report of the Committee on Electricity be accepted as information.

Respectfully submitted,

The Committee on Electricity,

W. M. Vandersluis, *Chairman.*

REPORT OF COMMITTEE I—ROADWAY

Geo. S. Fanning, *Chairman;*
J. B. Akers,
C. W. Baldridge,
E. J. Bayer,
W. G. Brown,
G. H. Burnette,
Paul Chipman,
A. A. Cross,
L. J. Drumeller,
G. B. Farlow,
P. D. Fitzpatrick,
L. C. Frohman,
J. A. Given,
J. N. Grim,
H. H. Harman,
F. W. Hillman,
C. T. Jackson,
G. E. Ladd,
W. J. Lank, Jr.,
Harold W. Legro,
E. R. Lewis,
H. T. Livingston,
J. A. Noble,
Roscoe Owen,
R. H. Pinkham,
W. C. Pruett,
C. S. Robinson,
A. E. Botts, *Vice-Chairman;*
L. S. Rose,
C. S. Sample,
P. T. Simons,
E. M. Smith,
H. E. Stansbury,
W. C. Swartout,
H. M. Swope,
J. B. Trenholm,
O. H. Wainscott,
Thomas Walker,
J. C. Wallace,
A. W. White,
F. E. Wiesner,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully presents its report on the subjects assigned:

1. Revision of Manual. No revisions are recommended except those to be made in connection with subjects 2 and 6.

2. Methods of Roadbed Drainage (Appendix A). This report concludes the consideration of this subject in accordance with the outline adopted in 1931. It is recommended that the matter in Appendix A, beginning with "(c) Maintenance" and ending at "Recommendations" be adopted for inclusion in the Manual to follow the matter adopted last year and that the changes in the Manual as listed under "Recommendations" be made. The purposes of these changes are to bring the definitions and the "Specifications for the Formation of the Roadway" in harmony with the recommended practice adopted for roadbed drainage, to remove from the Manual present matter on slides, water pockets, soft spots and ditching, the substance of which has been included in the above report or is obsolete, and to replace the figure on page 41 illustrating drainage with more comprehensive plates.

3. Study the service life of and prepare specifications for railway fence wire. Progress reports on this subject have been offered for several years covering various tests being made on fence wire. The Committee is keeping in touch with these tests and hopes to draw conclusions therefrom which will warrant submitting a specification next year.

4. Practice of jacking culvert pipe through fills (Appendix B). In making this report, the Committee had in mind providing a source of information for those unfamiliar with work of this kind from which they could secure sufficient data to prepare an estimate of cost and to carry out the work. It is recommended that the report be received as information.

5. Bearing power and other physical properties of soils including effect upon roadbed (Appendix C). In this report the Committee indicates some respects in which soil engineering is undergoing change and includes a glossary of soil terms. It is recommended that the report be received as information.

6. Methods of protection against drifting snow and of opening snow blockades (Appendix D). This report is a reconciliation of the report submitted last year as information and the matter on Snow Fences, Snow Sheds and Recommended Methods of Snow Removal now contained in the Manual. It is recommended that the matter

in Appendix D under the headings "Protection against Drifting Snow" and "Opening Snow Blockades" be adopted for inclusion in the Manual replacing the present material referred to above.

7. Specifications for galvanizing metal culvert pipe. Progress is reported on this subject with a recommendation that the subject be broadened to include a complete review of the Specifications for Corrugated Metal Culvert Pipe with a view to developing an American Standard.

8. Service life of culverts. This is a new subject and an extensive one. The Committee reports progress in organizing its work.

9. Methods of protection against drifting sand (Appendix E). Letters on this subject have been received from all parts of the world. The more interesting have been quoted in the report, which is offered with the recommendation that it be received as information and that the conclusions be adopted for inclusion in the Manual.

Respectfully submitted,

The Committee on Roadway,

Geo. S. Fanning, *Chairman.*

Appendix A

(2) ROADBED DRAINAGE

H. M. Swope, Chairman, Sub-Committee; G. B. Farlow, P. D. Fitzpatrick, H. H. Harman, G. E. Ladd, E. R. Lewis, C. S. Sample, P. T. Simons, E. M. Smith, T. Walker, A. W. White, F. E. Wiesner.

Consideration of this subject has been continued in accordance with the outline adopted in 1931 (Proceedings, Vol. 32, page 170). The subject-matter developed by this Committee has been adopted for publication in the Manual and is to be found in Proceedings, Vol. 32, pages 169 to 172; Vol. 33, pages 304 to 309; Vol. 34, pages 132 to 137. The following report concludes the study of this subject as outlined and is offered for publication in the Manual:

(C) MAINTENANCE

(I) Maintenance of Ditches

Causes

Ditch repairs may be necessary because of construction faults or deferred maintenance. If the gradient is unsuitable, the ditch may scour and cut, or accumulate silt.

Excessive grade tends to such rapid flow of water as to scour the bottom and undermine the slopes which slide in and form obstructions to flow, thus producing eddies and cross currents which aggravate the undesirable conditions.

Insufficient grade results in gradual silting. Unchecked growth of vegetation chokes the stream, obstructs water flow, and thus causes silt deposits.

Some soil wears away readily, the slopes are eroded by rainfall and undermined by the current of water in the ditch, unless the gradient is correct and the stream bed clear.

Maintenance

Alert and methodical inspection, with prompt remedy of large and small defects, is necessary to economical maintenance of ditches. The object is to preserve the original section as nearly as possible by preventing obstructions which tend to divert or

obstruct the flow. Repairs to drainage ditches should be made when conditions require, but a general program of repairing and cleaning should be conducted annually, preferably in the fall.

Erosion may take place at curves, especially during high water, and can be prevented by the placing of riprap, brush bundles, or concrete blankets.

Excessive grades may be counteracted with riffle dams of brush, stone, or other available material. While vegetation may be grown to prevent slope erosion, it should not be permitted to restrict the cross-section of the ditch, which should be kept free of all obstacles to free flow of water.

Obstructive snow and ice must be cleared from ditches for their preservation, to prevent wash, and to prevent the hazard of ice forming on the track during alternate thawing and freezing weather.

Intercepting and drainage ditches, other than side ditches in cuts, should be cleaned by hand work, teams and scrapers, power shovels or drag lines, depending upon the size of the ditch and kind and volume of material to be handled.

Ditching of ordinary material in side ditches in cuts may be subdivided into two principal classes:

1. Shallow Cuts
2. Deep Cuts

1. Shallow Cuts

On lines where ditching is done currently the work can usually be performed by hand or with spreaders equipped with wings for shaping ballast and roadbed shoulders, ditches and slopes. If maintenance has been deferred and the volume of material to be handled is large, teams with scrapers are economical in cuts sufficiently wide for safe operation.

2. Deep Cuts

On lines where ditching is done currently the work can usually be performed with spreaders. If the volume of material to be removed is small, hand labor, with motor cars, push cars and dump beds, wheelbarrows or trackbarrows should be considered.

In either of the above classes other means of ditching may be necessary when an accumulation of dirt from the spreading process fills the available space outside of the ditch. Deferred maintenance or the nature of the material involved may also make this necessary.

Where the volume of cleanings is large or the points of disposal remote, it will usually be more economical to use power ditchers.

Auxiliary track and small cars may be used economically on heavy traffic lines where there is sufficient clearance, provided the haul is long and the volume of material to be handled would justify the initial cost of the plant installation.

In all cases where the material is cast out it must be so placed to prevent it from washing back into the cut. Material removed from side ditches should never be cast upon the adjacent slope.

When waste dirt is disposed along embankments, it should be wasted at an elevation below the bottom of the ballast.

The use of work trains with hand labor is generally uneconomic, and is not recommended.

Ditching Machines

There are a number of items and conditions which should be considered before undertaking work with ditching machines and their equipment—interest on investment, depreciation, upkeep, work train service and interruption to traffic are vital items which

should not be overlooked. Equipment of this class has advantages which should also be taken into consideration. Ditching machines have a wide scope of operation; they will move large volumes of material in a comparatively short time; they make it practicable to utilize the material excavated for bank widening, trestle filling, if material is suitable, or other like work.

The use of power ditchers and their equipment is recommended in work where the cuts are long and deep, or where the volume of material to be moved is large, or where the material is wet and difficult to handle by other methods. Their use is also recommended where cuts are resloped or widened to such a limited extent as not to justify the use of power shovel. Under similar conditions they may be used for widening embankments. They are particularly efficient in removing small slides or other like emergencies where material is wet or hard to handle.

The chief considerations relative to use of such equipment is density of traffic and the volume of work to be performed.

The shaping of the roadbed and ditch after ditching should be performed by a spreader, when the nature of the material and the width of the cut will permit. Otherwise this work must be done by hand.

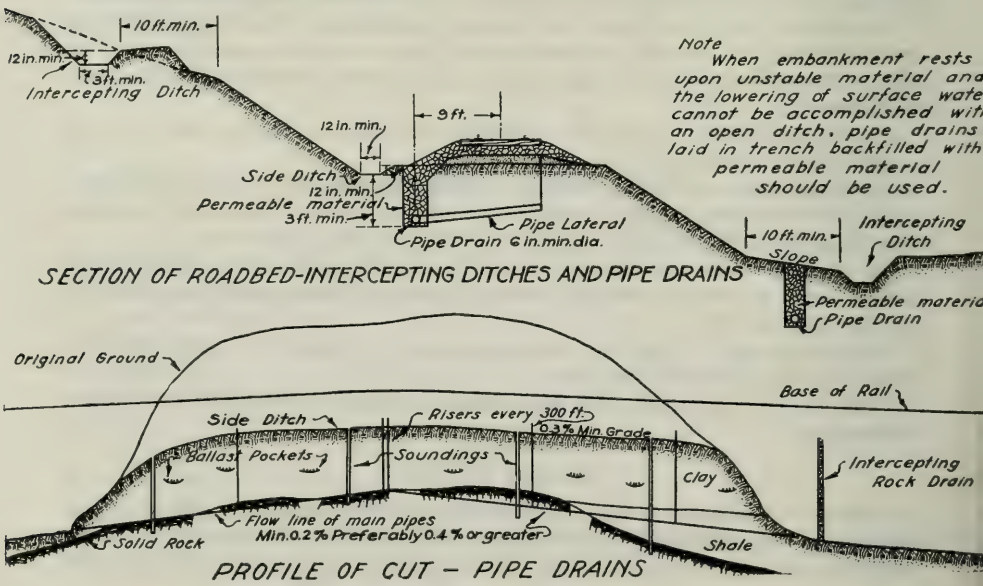
(II) Maintenance of Drains

Pipe Drains

1. General: Drainage systems are expensive and valuable. After installation the drains must be given enough care and attention to obtain from them the maximum life and service. Record plans made at the time of construction should be carefully preserved for reference and any changes made promptly noted thereon.

2. Inspection: In addition to a yearly inspection, roadmasters, track foremen, and others responsible for their maintenance, should make periodic inspections to see that the drainage systems receive adequate maintenance.

3. Markers: Limits of covered drains should be marked with adequate signs to facilitate inspection and maintenance.



4. Outlet ditch: Ditches leading from outlet pipes should be kept clean, with adequate width, depth, and grade to insure proper drainage. Side banks should be maintained with sufficient slope that the material involved will not cave. Ditches should be maintained free of vegetation, debris and other obstructions. Irregularities in alinement and grade tend to cause silting and scouring and should be avoided.

5. Outlet pipes: Screens on outlet pipes should be kept in place to prevent small animals entering pipes. When silting occurs at outlet, screens should be removed and the outlet cleaned. Special care should be given outlets to make certain that stoppage does not occur.

6. Overflow: Occasionally outlet pipes discharging near bridges and culverts are subject to overflow or backwater during high water. Inspection should be made as soon as water recedes and if necessary the pipe drainage system should be flushed.

7. Flushing: Frequent inspection of the mains should be made through the risers. Any tendency to silt should be carefully watched and when it occurs to a marked degree, the entire system of mains should be flushed with hose from water car or other convenient supply. This is especially necessary for systems involving light grades.

8. Vegetation: Trees, bushes or vegetation with deep roots should not be allowed to grow near any line of sub-surface drain pipe. The roots, seeking water, may fill the pipes and cause stoppage of the system.

9. Failure: Rapid silting of main drains indicates serious trouble; the obstruction must be located and removed. In excavating for obstructions care should be exercised to prevent fouling the porous material over the drains. The excavation should be backfilled with permeable material as described in B–II–9. Any tendency toward further development of water pockets or soft spots and heaving should be studied, and test holes dug to determine direct cause of failure. If failure caused by defect in pipe drains occurs, immediate repairs should be made. If heaving is due to obstinate water pockets or soft spots that are not tapped with laterals, additional laterals should be installed.

French or Rock Drains

1. Outlets: Screens covering ends of drain pipes in rock drains should be kept in place to prevent small animals from entering.

2. Outlet ditches: When a ditch is necessary to provide an outlet for the rock drain, it should be well maintained to prevent silting and provide a rapid get away of the water flow from the drain.

3. Silting: To avoid silting of the voids in rock drains the embankment adjacent to the drains should be built up or raised to direct drainage away from them.

(III) SPECIAL PROBLEMS OF MAINTENANCE

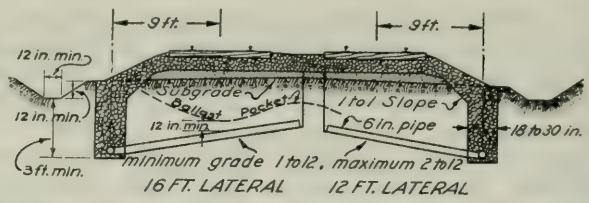
Soft Spots and Water Pockets

1. Occurrence

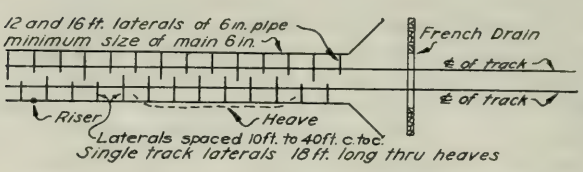
Soft spots and water pockets have existed for many years and in certain localities since construction.

They have increased and become more noticeable with increasing density of traffic and the use of heavier equipment.

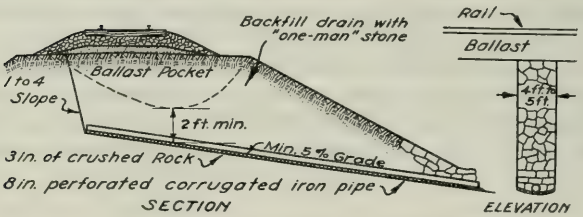
Soft spots and water pockets exist in localities where soil conditions are unfavorable to satisfactory maintenance, particularly in clay. They will be found in both fills and cuts, but more generally in clay cuts.



SECTION OF CUT-PIPE DRAINS



PART PLAN - ROCK AND PIPE DRAINS



FRENCH OR ROCK DRAINS

In soft spots the ballast has generally been beaten down into the roadbed, forming a trough or pockets under the track, the subballast and roadbed being pushed out laterally and oftentimes raised, forming walls which prevent the water draining from the track. This condition invariably results in water pockets.

The usual methods of surfacing and tamping track have no particular effect.

2. Importance

The elimination of soft spots and water pockets is of vital importance for safety under present high speed and heavy wheel loads. Higher speeds and heavier wheel loads, with resulting heavy impact, will develop soft spots in roadbeds which have adequately supported lighter loads at lower speeds.

Soft spots and water pockets should be given prompt attention as they soon develop into serious defects. The longer they exist, the more hazardous they become and the greater the resulting maintenance expense, as well as the greater expense involved in providing a permanent remedy.

3. Treatment

Soft spots and water pockets result in conditions so nearly alike that the treatment, where it is practicable to remedy the trouble by drainage, is the same.

In cuts a system of pipe drains as outlined in section B–II–9 above is recommended. Test holes should be made at intervals frequent enough to determine accurately the profile of the bottom of the water pockets. Lateral drains should be spaced so as to tap all of the pockets, sixteen feet center to center will usually suffice. The main and laterals should be placed into stable material, with the minimum depth of the main 24 inches and of the lateral 12 inches below the bottom of the deepest pocket, unless the surface of solid rock or hard shale lies at a less depth, in which case the minimum depth of the main can be reduced to 12 inches below the bottom of the deepest pocket. Quite often the "softest" cuts are of a clay material overlying rock or shale. Usually this harder underlying stratum is not on a uniform plane, but is irregular, and if it is uniform it will not conform with the grade of the main. To prevent dislocation of the drain pipe it is well to place the pipe into the rock or shale to at least a depth equal to the pipe's diameter. Other minimum requirements given in B–II–9 should be adhered to.

Frequently single track cuts contain soft spots and water pockets to the extent that lateral displacement or heaving is prevalent on both sides of the track. In this case a subdrain system of mains with laterals should be placed on each side of the track. When one main is used it should be located on the side of the track in which displacement or heaving takes place, which is usually the upper side (with respect to the natural ground surface). If heaving does not occur, the main drain should be placed on the upper side of the track.

Where soft spots cannot be effectively drained, the bearing area of the track structure must be increased.

In fills, French or rock drains as described in section B–II–10 are recommended.

In side hill cut—fill sections, French or rock drains are recommended, supplemented (where it is necessary to intercept water flowing directly from the cut side into the water pockets) by pipe drains on the cut side.

Slides

Definition

Slide.—A superficial, gravitational earth movement.

General

1. Slides usually occur in unconsolidated material, but may occur in open faces of rock formations. Gravity is a primary cause, supplemented by lubricating water, undermining (natural or artificial), clay-type material, certain types of geological structure, or increase of load; and in the case of rock slides specifically, by joint planes, fault planes, schistose structure, or strata dipping towards an open face. In the latter cases, causes are accentuated often by clay seams in partings of the rock.

2. Each slide should be considered as a problem by itself.

3. The cause of the slide should be determined. Thorough and expert examination should be made of soils, drainage conditions and geological conditions related to the cause of the slides. The thickness and volume of the unconsolidated material should be ascertained in order to arrive at a decision as to economic preference between the removal of sliding material and the application of suitable control methods. The removal or prevention of the cause is as important as the restoration of the roadway.

4. Piles or retaining walls for the prevention and cure of slides are not recommended; but their use is permissible for temporary repairs and in special cases.

5. Surface water should be intercepted and diverted by surface ditches described in B–I.

6. Underground water should be drained away, or preferably intercepted at its underground source, and diverted. Slides due to flow of underlying material may be controlled by drainage around the toe of slide by constructing French drains containing perforated pipe. (B–II–10). When this unstable underlying material is deep, tunneling to intercept the flow may be necessary. When feasible, water cut-off is usually more economical and effective than trenching or tunneling. French drains with perforated pipe are sometimes necessary to remove underground water from the slide itself when it is impractical to remove all the sliding material in hillside or "cut" slides. This control method is usually coupled with removal of sliding material, slope modification, and water cut-off, or intercepting drainage.

Fills frequently slide because of water flowing down grade in the ballast pockets, or from adjacent higher ground. Cut off drainage is the prevention. French drains (B–II–10) should be constructed across the upper end of the fill, in the first case, and through the water carrying strata in the latter. Where slides have developed in fills they may be drained and stabilized by constructing French drains, and sometimes supplemented by erecting a berm at the toe of the fill.

To prevent surface water entering fills, a 12″ coat of limestone screenings or other impervious material forming a blanket over the top and extending down the slope 10 to 20 feet is successfully used. The lower edge of the blanket should be well keyed in. Fissure filling and oil coating are also sometimes beneficial.

7. Depressions which have formed in unstable ground should be drained and any cracks which may have developed should be filled.

8. Terracing or flattening the slope lightens the load, and may lessen or prevent sliding. This may be done in addition to other methods of control. The removal of the entire moving mass in hillside or slides in cuts may be more economical than control methods.

9. Firmly compacted berms, approximately one-third the height of the fill, will help stabilize the fill and may be used in connection with drainage control methods. Weighting of the toe of a slide is useless if movement exists throughout the mass. When used it must rest upon, or be carried down to solid material.

10. A relocation of the line is sometimes necessary where the slide assumes the proportion of an avalanche.

Recommendations

The Committee recommends the adoption of this report for publication in the Manual, making the following changes in the 1929 Manual:

Page 23. Remove definition of slide.

Page 25. Under "Drainage" add definition: French Drain—Underground passages for water through the interstices among stone placed loosely in a trench.

Make the following revision to "Specifications for the Formation of the Roadway", pp. 28 to 36, inclusive.

Page 31. Add the following to Section 30, "Intercepting Ditches": "The material excavated from the ditch shall be deposited on the side of the ditch towards the cut, unless otherwise directed. The slope of the waste bank from its summit towards the ditch shall be as long as feasible. In crossing light depressions in hillsides, when directed, levees shall be constructed and the depression filled above the levee so as to bring its surface up to the grade of the ditch. The top surface of this fill shall be of puddled clay.

"Intercepting ditches, when ordered, shall be made on the upper side of the fills where the ground slopes towards the embankment. The cross-sections and locations of such ditches shall be designated. Unless otherwise ordered, the waste dirt shall be placed so as to provide a slope from the toe of embankment to the ditch. If required, they shall be excavated in advance of the construction of the embankment."

Pages 31 and 32. Replace all of Section 32, "Subdrains", with the following:

"Pipe subdrains shall be constructed of the material and size and in the location shown on the plans, or as directed, and to the depth and grade established for them. The cross-section of the trenches shall conform with the plans, and the trench shall be excavated and the pipe laid to true line and grade. Sufficient cribbing or shoring must be used to prevent caving of the trench excavations. All trenches shall be backfilled with an approved permeable material, kept free from dirt, dust and other foreign material. The finished section of the backfill shall conform with the plans."

Page 33. Add the following to Section 40, "Finishing Subgrade": "It must be maintained in this condition until the ballast is placed, (or until accepted). Any backfilling necessary to make a smooth surface shall be made of the same material as exists in the roadbed.

"Where roadbed, in either cuts or fills, is composed of a more or less clay material, all construction tracks shall be removed after the work has been brought to grade and the subgrade rolled with a road roller weighing about 10 tons and thus brought to proper crown and surface."

Page 40. Remove all material under "Slides", Articles 1 to 12, inclusive.

Page 41. Replace Figure 2 with two plates illustrating roadbed drainage.

Page 46. Remove "Means for Prevention or Cure of Water Pockets in Roadbed", Articles 1 to 6, inclusive.

Page 50. Remove all material under "Soft Spots".

Pages 50, 51 and 52. Remove all material under "Ditching".

Appendix B

(4) PRACTICE OF JACKING CULVERT PIPE THROUGH FILLS

J. A. Noble, Chairman, Sub-Committee; J. B. Akers, A. A. Cross, L. J. Drumeller, J. N. Grim, G. E. Ladd, R. H. Pinkham, C. S. Robinson, L. S. Rose, W. C. Swartout, O. H. Wainscott.

This report is based on information secured from the following railways: Atlantic Coast Line, Atchison, Topeka & Santa Fe (Photograph 3), Baltimore & Ohio, Bessemer & Lake Erie (Photograph 4), Canadian National, Chesapeake & Ohio, Chicago, Burlington & Quincy, Central of New Jersey, Central of Georgia, Erie, Great Northern, Illinois Central, Louisville & Nashville, Maine Central, Minneapolis, St. Paul & Sault Ste. Marie, New York Central, Northern Pacific, Reading, St. Louis–San Francisco, Southern, Southern Pacific, Union Pacific, Western Pacific.

Valuable information was also furnished by the Armco Culvert Manufacturers Association, Ingot Iron Railway Products Company (Photographs 1 and 2), The Massey Concrete Products Corporation, and the State Highway Department of Ohio (Photographs 5 and 6).

The Committee recommends that this report be accepted as information and the subject discontinued.

PRACTICE OF JACKING CULVERT PIPE THROUGH FILLS

The installation of pipe culverts, where conditions are favorable, by pushing them into position with jacks, is safe, fast, and will usually be cheaper than other ways of placing the pipe.

Kinds of Pipe Suitable for Jacking

The most widely used material for pipes installed by the jacking process has been corrugated iron, but cast iron pipe of the bell and spigot type, also special cast iron pipe has been used, and a considerable quantity of concrete pipe has been installed by this method. The proper kind to be used in any particular case can be determined by a consideration of installation cost, probable life, and maintenance cost.

If corrugated pipe is selected, it should be fabricated especially for jacking from 8 gage metal in lengths convenient to handle, say 12 to 18 feet, and should be punched and matchmarked for field riveted joints. This pipe is made up in multiples of 2 feet, and an extra charge is made for odd lengths. It can be had with the invert paved with asphaltic cement, if it appears probable the life of the pipe will be lengthened thereby.

If cast iron pipe is to be used, Class B will be suitable for most installations. The pipe may be bell end or have a special type of joint. As the latter gives the pipe an unbroken outside surface, it will simplify the jacking procedure.

Concrete pipe is available with special reinforcement and ship-lap joints and presents a smooth outside surface. It is usually made in 6-ft. lengths.

Size of Pipe

Pipe from 24 inches up to 68 inches in diameter has been placed by jacking, without special boring equipment. Ordinarily 42-inch pipe is the least size which should be used, as smaller sizes are hard to work in and little if anything will be saved by their use.

Approach Trench

When starting a jacking operation the bank is excavated so that a vertical face is presented to the entering pipe. The most economical length of this approach cut or trench will be determined by the relative costs of jacking and of excavation. Where the fill is high 15 or 20 feet will be about right in most cases. It must, of course, not extend to a point where the stability of the track would be affected. For long lines of pipe it will usually be desirable to place 15 or 20 feet of pipe in open trench on the opposite side of the embankment also, although if the jacking is easy, it may pay to place all of the pipe in this manner. The approach trench is usually excavated by hand, but in some cases a power shovel can be used to good advantage. If concrete or cast iron pipe is being placed it will pay to have a crane to line up or rack the pipe, and one of the crawler type excavators can do this and also dig the approach trench.

Direction of Jacking

As a general proposition, the pipe should be jacked up-hill to facilitate drainage in case water is encountered in the fill, and to prevent interruptions from storm water. If concrete pipe is used, it is more easily kept on grade if jacked down-hill due to the weight of the pipe constantly tending to work the front end down, however this tendency can be controlled without great difficulty. In some cases shafts are sunk, and the pipe jacked both ways from the shaft. This method simplifies the back-stop problem, and decreases the length of pipe to be jacked.

Unloading and Lining up the Pipe

Corrugated pipe may be unloaded without special equipment, but concrete and cast iron pipe are best handled with a crane. After being landed alongside the track, the pipe can be rolled to the bottom of the fill by ropes.

Care must be used in handling concrete pipe to prevent its being chipped, and corrugated pipe also should be carefully handled, as it has been punched and matched for field rivets, and if the ends are bent or deformed, extra expense will be incurred for correcting these conditions.

If the pipe to be jacked comes in short lengths, it should be lined up or racked on timbers extending at right angles to the direction of jacking, and placed so that the pipe can be rolled on to the guide timbers in front of the jacks quickly and with little effort. This is not essential if corrugated pipe is used, as the individual sections will be longer.

The Jacking Set-up

The type of back-stop necessary will depend upon the nature of the ground in which it is set, the length of pipe to be jacked and the character of the material to be penetrated. For average conditions, a back-stop constructed as shown in Fig. 2 will be satisfactory.

Guide timbers which may be of 7×16 material are set in the approach trench and carefully placed to line and grade; they should extend to the point where the pipe will enter the fill. If concrete or cast iron pipe is being placed steel angles on the inner edges of the guide timbers will be desirable. This is particularly true if a cutting edge is used on the leading joint of pipe.

Fig. 2 shows the kind of jacking frame ordinarily used. For corrugated and cast iron pipe, four 6×8 timbers framed to bear against the end of the pipe and leave sufficient opening for the excavated material to be removed will transmit the pressure from the jacking frame satisfactorily.

For concrete pipe a special jacking head is recommended by the manufacturers of the pipe, the details of its construction being shown in Fig. 3.

For concrete pipe a steel cutting edge or shoe is sometimes used, although if annular this is of doubtful value owing to the tendency of the pipe to dig into the bottom of the bore. A special sled-like shoe has been bolted to the lower part of the leading joint of pipe in some cases, and this will prevent the pipe from working below grade. The progress of the pipe, where such a shoe is used, must be carefully watched to prevent it getting above grade. A cutting edge is not necessary for corrugated iron pipe.

Jacks Required

The number of jacks required and their capacity depend upon the size and length of pipe to be jacked and the nature of the embankment material. For the average job two 15 ton track jacks and two 50 or 75 ton high speed ball bearing high lift jacks should be provided. The operation can be started with small capacity jacks and they will be useful for taking up the compression in the blocking after the jacking gets too heavy for them. To avoid frequent re-setting, the jacks should have not less than a 12 inch lift. On account of the greater weight involved, higher capacity jacks will be required for placing concrete and cast iron pipe than for corrugated pipe.

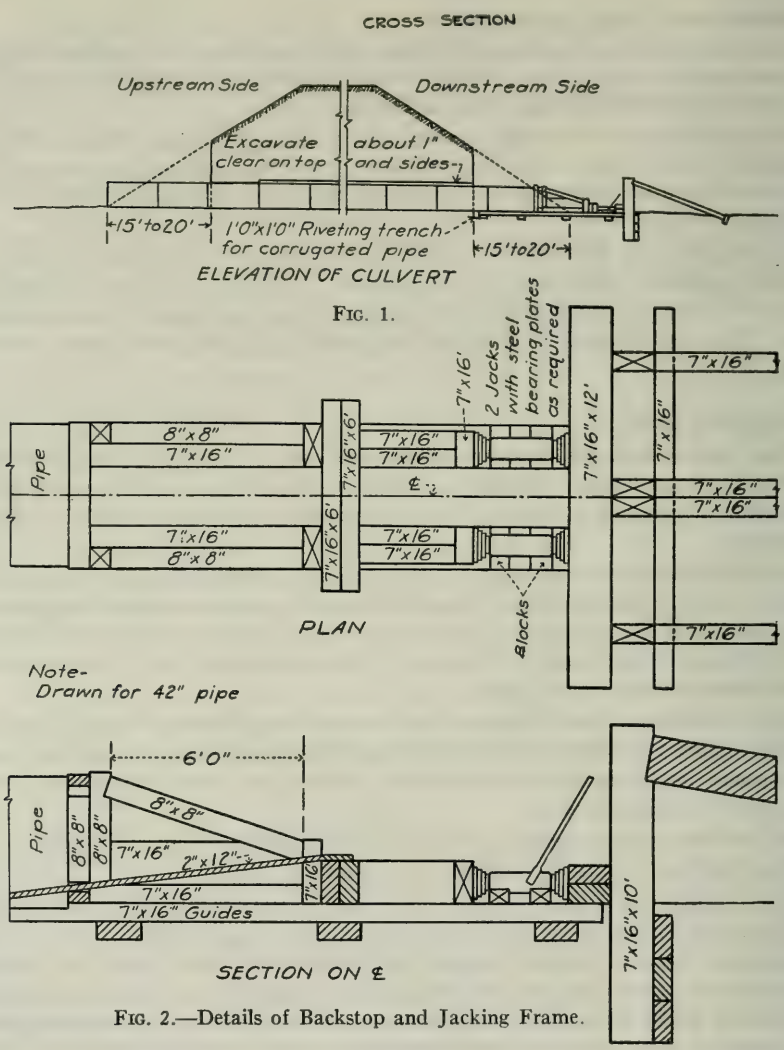


Fig. 1.

Fig. 2.—Details of Backstop and Jacking Frame.

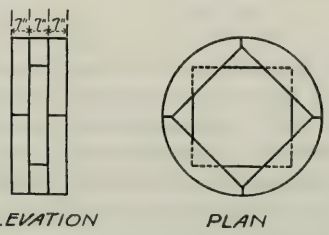


Fig. 3.—Showing Wood Jacking Head for Concrete Pipe.

Force

The number of men required for an average job will be about as follows:

1 Foreman,
1 Man digging,
1 Loading dirt into the wheel barrow or whatever is used for disposal,
1 Man taking waste material away,
2 Men operating jacks.
Where progress is rapid, an additional man will be needed to help remove spoil, and in heavy ground or on long lines of pipe two men on each jack will expedite the work.

This force will place from 10 to 16 feet of pipe per eight hour day under favorable conditions.

Jacking Procedure

The preliminary work, such as constructing back-stop, jacking frame, placing of guide timbers and excavation of approach trench having been done, the work proceeds in the manner described in the following: A joint of pipe is rolled on to the guide timbers and jacked against the bank. Digging is then begun from inside the pipe, the excavated bore being made to grade at bottom, and about one inch larger than the pipe on sides and top. The man digging casts the spoil back into the pipe whence it is loaded into a wheel barrow or car by his assistant. Another man wheels the spoil out through the pipe to the waste bank. It will sometimes be necessary to have an additional man to help pull the loaded barrow up the incline out of the pipe. Where two barrows are being used, the man handling the ingoing barrow helps his partner up the incline. The jacking goes forward continuously until the limit of travel of the jacks is reached. Additional blocking is then placed and the process continued until there is room for another joint of pipe.

The grade and line of the pipe must be carefully watched and corrected when necessary. This can be done by wooden wedges. If available, an engineer's transit will be the most satisfactory way to keep the pipe properly lined up, but sufficiently accurate work can be done with a straight edge and spirit level if care is taken in using them.

Joining the Pipe

Corrugated pipe is joined by riveting the various sections together as each additional one is rolled into place. To accomplish this, a trench about one foot wide and one foot deep at right angles to line of jacking is necessary. The usual location of this trench is shown in Fig. 1. Corrugated bands are sometimes used at the joints and will ordinarily be preferable on the inside. Rivets can be driven cold, but better results will be secured if they are heated.

If the pipe is of concrete with ship-lap joints, some form of cushioning between the joints will reduce the likelihood of breakage due to concentrated pressure. A piece of ½ inch Manila rope stuck to the pipe with some form of asphaltic cement will be satisfactory for this purpose. After the pipe is in final position, the joints can be grouted.

Cast iron pipe of the bell and spigot type requires no special provision for joints. If it appears desirable after pipe is in place, the joints can be grouted or filled with asphaltic cement.

Digging Methods

The tools commonly employed for digging are short-handled picks and shovels. In some soils an adze will be found useful. Compressed air diggers can frequently be

used to good advantage, and where rock or shale is encountered, air drills will be needed. In long pipes, the exhaust from air tools is of value in ventilating the pipe.

The distance to which excavation can be carried ahead of the pipe will depend upon the character of the ground and depth below the track. In very favorable soil the distance may be as much as 4 feet. Ordinarily it will be one or two feet. It is dangerous to carry excavation further ahead of the pipe than is absolutely necessary.

In short pipes of large diameter, artificial light will not be necessary, but in most installations the work will be expedited by the provision of ample illumination. Oil lanterns are largely used, but if available electric lamps will be found more satisfactory.

Waste Disposal

Where the diameter of the pipe permits, spoil is generally handled from the pipe by wheel barrows. One barrow will be enough for short pipes; 2 will be desirable for long pipes where the jacking proceeds at the rate of one foot or more per hour.

Another method of removing spoil is to load it into a flat-bottom box equipped with wheels, which is pulled back and forth by means of a rope. This box is emptied into a wheel barrow at the end of the pipe, and the spoil wheeled away to the waste bank.

Procedure in Unstable Soils

The jacking method is not well adapted to placing pipe in unstable soils, and before undertaking an operation of this kind a very thorough investigation of conditions should be made. Borings into the fill where there is doubt as to the nature of the material may be desirable.

If jacking is decided upon it will probably pay to prosecute the work continuously to minimize the tendency of the material to freeze around the pipe.

The excavation should not be carried more than a few inches ahead of the pipe.

Wet sandy soils can be de-watered by means of well points with probably beneficial results.

If the pipe sticks, it may have to be jacked from both ends and possibly from intermediate shafts. The resistance to jacking, caused by material settling in the corrugations of corrugated pipe can be reduced by riveting strips of sheet iron lengthwise on the exterior.

The approach trench should be properly sheeted and braced on the sides and working face.

For obvious reasons bell and spigot type pipe will not be as suitable for placing in unstable soils, as that presenting a smooth exterior.

Protection of Pipe Against Percolation and Scour

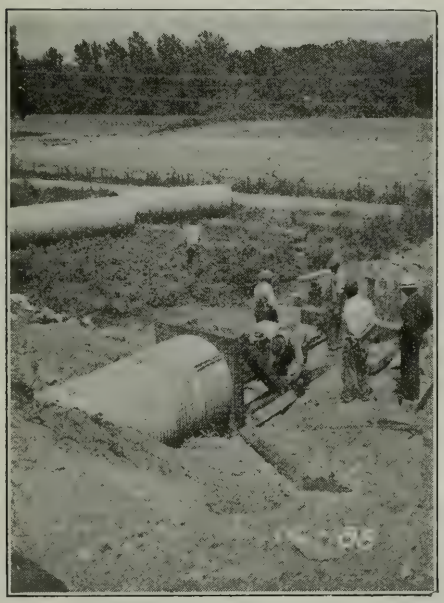
If it is anticipated that the pipe will discharge under head for any considerable period, and particularly if it lies in easily eroded material, the same precautions against percolation along the outside should be taken, as in the case of conduits through earth dams.

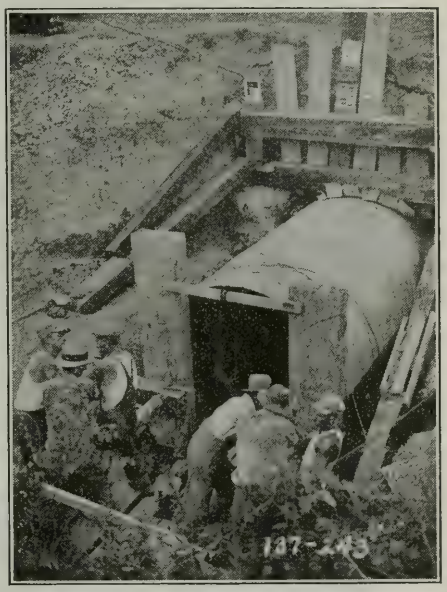
Concrete collars or cut-off walls will be found effective for this purpose. It will likely be impracticable to place more than two of these on one pipe due to the amount of excavation and other difficulties involved. The collars therefore should be made larger than if they were built at closer intervals. In addition concrete pavement on the upstream end extending beyond the limits of the open excavation and tied in to the pipe headwall will add to the security of the installation. If the fill does not settle around the pipe the resulting space may be filled with a mixture of mud and cement, about one sack of the latter to the cubic yard.

In extreme cases outlet works for dissipating the energy of the issuing water will be justified.

In all installations, the back-fill at each end should be well rammed around the pipe, and sometimes the excavation for the last joint of pipe can be made slightly smaller than the pipe, thus increasing the resistance to percolation.

If it is necessary to protect the ends against scour, it can be done by concrete pavement or riprap, except that as mentioned in the foregoing, extreme cases will require more extensive protection.





Corrugated Metal Pipe

54″ Diam. 38′ long, 12′ fill.
Missouri Pacific R. R.
Photograph No. 1.

84″ Diam. 50′ long, 14′ fill.
Pennsylvania R. R.
Photograph No. 2.

Conclusions

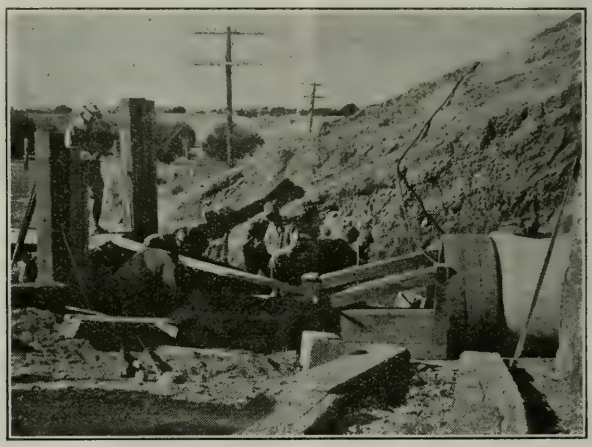
The conclusions of the Committee are that where conditions are suitable, the placing of pipe culverts by the jacking process is feasible and will save from 30% to 50% of the cost of placing the pipe by the open trench method and will be cheaper than tunneling. Pipes have been installed by this process in practically all types of material from rock to quicksand. The advantages of the method are:

1. Usually lower cost,
2. No interruption of traffic,
3. Minimum disturbance of roadbed, and consequently little or no subsequent settlement.

This method is particularly applicable where more than one track is involved, where the fill is high, where the material to be penetrated is clay or similar soil that will arch or stand up well and where the traffic is heavy.

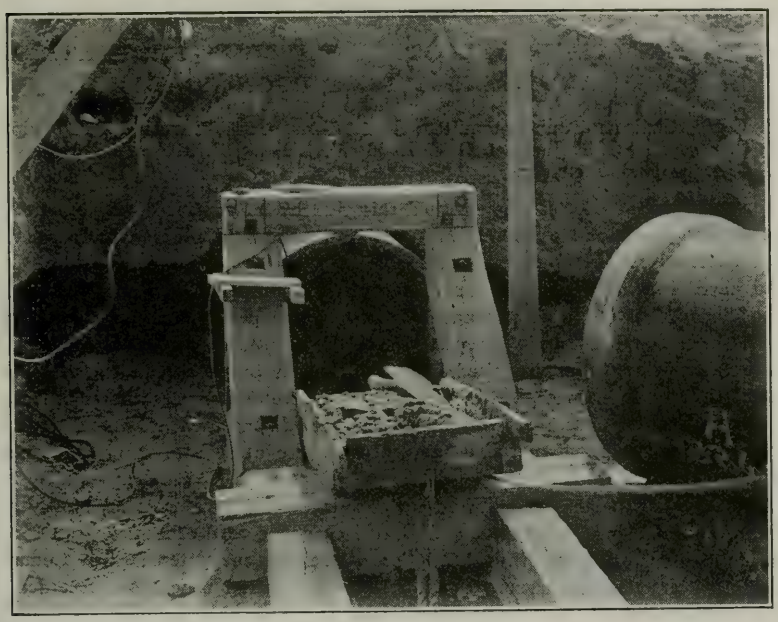
Costs will be higher, although not necessarily prohibitive in unstable soils and embankments containing boulders, stumps, waste from rock cuts, or similar obstructions.

Before it is decided that jacking is the proper method to use, all conditions involved in the operation should be investigated, and if the economy to be obtained appears doubtful, cost estimates for open cut placement or tunneling should be compared with the probable cost for jacking. Such estimates should include expense due to interference with traffic, and excess maintenance until embankment becomes stabilized. Generally, jacking operations will have little or no effect upon the stability of the track, and if subsequent settlement is experienced, it will be very slight.

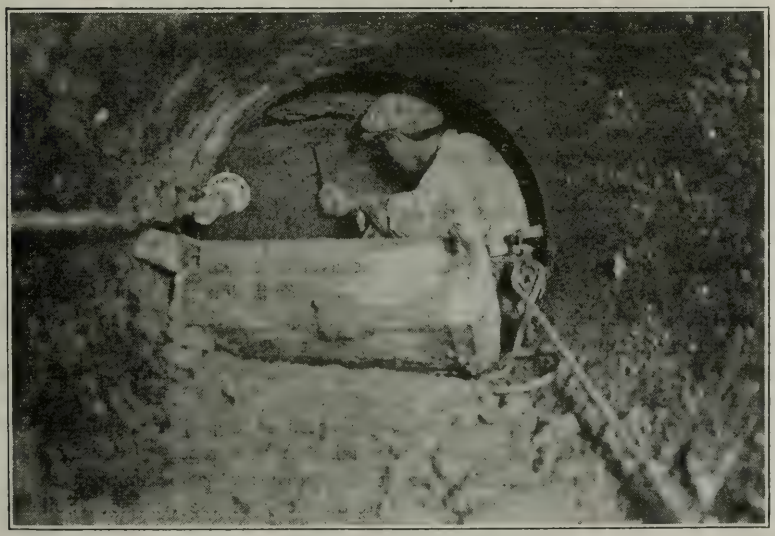


48″ Concrete Pipe.
A. T. & S. F. Ry.
Photograph No. 3.

Bessemer & Lake Erie Railroad.
Jacking 68″ Flat Base R.C. Pipe
Photograph No. 4.



Jacking Frame and "Boat".
Cast Iron Pipe. 30" Diameter 132 Feet Long. Ohio State Highway Dept. Photograph No. 5.



Excavating Ahead of Pipe Showing Light and "Boat".
Cast Iron Pipe. 30" Diameter, 132 Feet Long. Ohio State Highway Dept. Photograph No. 6.

Appendix C

(5) BEARING POWER AND OTHER PHYSICAL PROPERTIES OF SOILS, INCLUDING EFFECT UPON ROADBED

H. W. Legro, Chairman, Sub-Committee; J. B. Akers, G. H. Burnette, Paul Chipman, L. C. Frohman, C. T. Jackson, G. E. Ladd, W. J. Lank, E. R. Lewis, Roscoe Owen, L. S. Rose, J. B. Trenholm.

The scope of the subject was enlarged this year by assignment of the broader field of the bearing power and other physical properties of soils in addition to consideration of their effect on roadbed performance.

Advanced interest in the relation of the physical properties of soils to the settlement of foundations of structures and to the subgrade performance of transportation ways has been manifest during the past decade. Soil research by laboratory and field tests, revealing hitherto unrecognized effects of certain properties on the stability of supported structures, has stimulated this interest. Investigators are far from agreeing as to the application of the knowledge thus far gained, but there is general agreement that many of the concepts that have governed the use of soils to carry loads require revision.

There is a fairly extensive bibliography covering recent investigations, mostly along laboratory and highly technical lines, and a sad lack of recorded experience with foundation loads in terms of an adequate description of the soils encountered. The Committee is attempting practical evaluation of the results and partial conclusions recorded, but pending further study is not ready to do more this year than indicate some respects in which soil engineering is undergoing change, and to include a glossary of soil terms as a guide to identification of the field characteristics of the soil material as found in its natural state.

The present practice of selecting the admissible soil pressure under footings, slabs, etc., from tables given in building codes ignores factors that appear important to many engineers as influencing settlements; for example, the size and shape of the loaded area and the depth of the foundation below the surface of the ground. Tests reported* indicate that for cohesive soils (such as clays), the settlement produced by a given load per unit of area may increase almost in direct proportion with the diameter of the loaded area. For cohesionless soils (such as sands), it has been observed that the size of the area has little effect.

Settlement is also dependent on the depth of the foundation, i. e., the greater the depth, normally the greater the bearing power, more especially of cohesive soils, due to natural pre-consolidation by the pressure of the overlying soil.

Observations of differences in the behavior of foundation piles under driving and under static load, and of an individual pile as compared with a group, have led to critical discussion of pile-driving formulas in present use.

Few, if any, investigators of the behavior of soils have yet attempted definite conclusions in the matters of the preceding paragraphs.

The terminology of soils given here is presented as a preliminary listing of soil characteristics. With some modifications, it is taken from a report* by W. I. Watkins and Henry Aaron of the U. S. Department of Agriculture, who compiled the terms largely from a report of the Committee on terminology of the American Soil Survey Association at its eighth annual meeting, March, 1928.

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* "The Science of Foundations," by Charles Terzaghi, Transactions, Am. Soc. of C. E., Vol. 93 (1929), p. 273–276 incl.

* "The Soil Profile and the Subgrade Survey," Public Roads, Vol. 12 No. 7 (September, 1931).

TERMS IDENTIFYING SOILS

Soil Map Terms

Soil Profile.—A vertical section of the soil layers from the surface into the underlying unweathered material.

Soil Horizon.—A layer or portion of the soil profile more or less well defined in appearance or other characteristics.

Soil Class.—A classification of soils based on texture only, as sand, sandy loam, clay, etc. It is determined in the field by the appearance and feel, and in the laboratory by mechanical analysis; textural grade.

Soil Type.—A soil which over the full extent of its occurrence has relatively uniform texture of the surface soil and relatively uniform profile characteristics in the upper horizons; the unit of soil mapping. The name of the soil type is a combination of a series name and the class designation, as for example, Orangeburg sandy loam.

Soil Series.—A group of soil types that have profiles (of the upper horizons) closely similar in all respects except the texture of the surface layer.

TEXTURE

Texture is a term indicating the size of the individual soil grains or particles and the proportions of material of each size present in any given case.

As the soil is usually made up of particles of widely varying size, the textural terms express the average effect or the combined effect of all these grain sizes. They may indicate the predominance (in quantity or in textural effect) of a certain group of grains.

Texture is determined by mechanical analysis, a laboratory process of separating the soil into groups of grain sizes. The system of mechanical analysis used by the U.S. Bureau of Chemistry and Soils separates the soil material into seven grain sizes or "separates" having the following sizes and names:

2 to 1 millimeter, fine gravel
1 to 0.5 millimeter, coarse sand
0.5 to 0.25 millimeter, sand
0.25 to 0.10 millimeter, fine sand
0.10 to 0.05 millimeter, very fine sand
0.05 to 0.005 millimeter, silt
Below 0.005 millimeter, clay

In the following paragraphs are given the proportions of certain of the grain sizes found in the major soil textures:

Sands contain less than 20 per cent of silt and clay. (Include coarse, fine, and very fine sands.)

Sandy loams contain from 20 per cent to 50 per cent of silt and clay but do not have over 20 per cent of clay. (Include coarse, fine, and very fine sandy loams.)

Loams have more than 50 per cent of silt and clay combined, but have less than 50 per cent of silt and less than 20 per cent of clay.

Silt loams have more than 50 per cent of silt and less than 20 per cent of clay.

Clay loams have more than 50 per cent of silt and clay combined but less than 50 per cent of silt and between 20 per cent and 30 per cent of clay. (Include sandy clay loams, clay loams, and silty clay loams.)

Clays have more than 50 per cent of silt and clay combined and more than 30 per cent of clay. (Include sandy clays and silty clays.)

In the field, texture is determined by the feel of the soil mass when rubbed between the fingers. The following statements give the obvious physical characteristics of the basic textural groups:

Sand.—Sand is loose and granular. The individual grains can readily be seen or felt. Squeezed in the hand when dry it will fall apart when the pressure is released. Squeezed when moist, it will form a cast, but will crumble when touched.

Sandy Loam.—A sandy loam is a soil containing much sand but having enough silt and clay to make it somewhat coherent. The individual sand grains can readily be seen and felt. Squeezed when dry, it will form a cast which will readily fall apart, but if squeezed when moist a cast can be formed that will bear careful handling without breaking.

Sands and sandy loams are classed as coarse, medium, fine, or very fine, depending on the proportion of the different sized particles that are present.

Loam.—A loam is a soil having a relatively even mixture of the different grades of sand and of silt and clay. It is mellow with a somewhat gritty feel, yet fairly smooth and slightly plastic. Squeezed when dry, it will form a cast that will bear careful handling, while the cast formed by squeezing the moist soil can be handled freely without breaking.

Silt Loam.—A silt loam is a soil having a moderate amount of the fine grades of sand and only a small amount of clay, over half of the particles being of the size called "silt." When dry it may appear quite cloddy, but the lumps can be readily broken, and when pulverized it feels soft and floury. When wet the soil readily runs together and puddles. Either dry or moist it will form casts that can be freely handled without breaking. If squeezed between the thumb and finger it will not "ribbon" but will give a broken appearance.

Clay Loam.—A clay loam is a fine-textured soil which breaks into clods or lumps that are hard when dry. When the moist soil is pinched between the thumb and finger it will form a thin ribbon which will break readily, barely sustaining its own weight. The moist soil is plastic and will form a cast that will bear much handling. When kneaded in the hand it does not crumble readily but tends to work into a heavy compact mass.

Clay.—A clay is a fine-textured soil that forms very hard lumps or clods when dry. When the moist soil is pinched out between the thumb and fingers it will form a long, flexible ribbon.

Gravelly or Stony Soils.—All of the above classes of soils, if mixed with a considerable amount of gravel or stone, may be classed as gravelly sandy loams, gravelly clays, etc., as stony sandy loams, stony loams, etc., or as sandy clay loams, sandy clays, etc.

Colloids (Soil).—Constituents of the soil having a particle size indicated by an average diameter not greater than 0.001 millimeter (1 micron), as designated by the U.S. Department of Agriculture, derived from the weathering and decomposition of soil minerals, together with organic matter, and greatly influencing the characteristics of the soil mass with which it is intimately associated, for example—cohesiveness.

Peat Soil.—Composed predominantly of organic material highly fibrous, with easily recognized plant remains.

Muck Soil.—Composed of thoroughly decomposed black organic material, with a considerable amount of mineral soil material, finely divided and with a few fibrous remains.

Leaf Mold.—The accumulation on the soil surface of more or less decomposed organic remains, usually the leaves of trees and remains of herbaceous plants; the A, or surface, horizon.

Floury.—Fine-textured soil consisting predominantly of silt (or flocculated clay with aggregates of silt size) which when dry is incoherent, smooth, and dust-like.

Gritty.—Containing a sufficient amount of angular grains of coarse sand or fine gravel, so that these dominate the "feel." Usually applied to medium-textured soils (loams) where the actual quantity of these coarse grains is rather small.

Heavy (textured).—Applied to soils of fine texture in which clay predominates, with dense structure and firm to compact consistency. The term is also applied to soils containing a somewhat higher proportion of the finer separates than is typical of that textural class (as a "heavy sandy loam.")

Light (textured).—Applied to soils of coarse to medium texture with a very low silt and clay content, incoherent, single-grained structure, and loose consistency. The term is also applied to soils containing somewhat higher proportions of the coarser separates than is typical of that textural class (as a "light loam.")

Sharp.—Containing angular particles in sufficient amount to dominate the "feel". Abrasive.

Smooth.—Containing well-rounded coarser particles and a predominance of the finer separates. Not abrasive.

STRUCTURE

The term "soil structure" expresses the arrangement of the individual grains and aggregates that make up the soil mass. The structure may refer to the natural arrangement of the soil when in place and undisturbed (as structural profile) or to the soil at any degree of disturbance. The terms used indicate the character of the arrangement, the general shape and the size of the aggregates, and in some cases may indicate the consistence of those aggregates.

Adobe Structure.—This term describes a soil which on drying cracks and breaks into irregular but roughly cubical blocks. The cracks are usually wide and deep and the blocks are from 20 to 50 or more centimeters across. (Adobe soils are usually heavy-textured and high in content of colloidal clay.)

Amorphous Structure.—A soil of fine texture having a massive or uniform arrangement of particles throughout the horizon. Structureless. Found only in soils of finest texture, where individual grains cannot be recognized.

Buckshot Structure.—Aggregates of roughly spherical shape, usually two or three millimeters in diameter, and of a hard consistence.

Clod (or cloddy) Structure.—Aggregates of irregular, angular shape, usually 4 centimeters or more in diameter and of a hard consistence.

Fine Cloddy Structure.—When most of the clods are close to the minimum size.

Coarse Cloddy Structure.—When most of the clods are 10 centimeters or more in diameter.

Columnar Structure.—A natural arrangement of the soil mass in more or less regular columns separated by vertical cleavage lines, and usually broken by horizontal cracks into sections with longer vertical than horizontal axes.

Crumb Structure.—Porous aggregates of irregular shape, rarely over 2 centimeters in diameter and of a medium to soft consistence.

Fine Crumb Structure.—Crumbs 5 millimeters or less in diameter.

Coarse Crumb Structure.—Crumbs 2 centimeters or more in diameter.

Crust (or crusted) Structure.—This term is used where the upper or surface horizon coheres into plate or crust distinct from the horizon immediately below it.

Crust-Mulch Structure.—An arrangement where a surface crust is underlain by an horizon of loose, incoherent particles of mealy, crumb, or granular structure.

Dense Structure.—Having a minimum of pore space and an absence of any large pores or cracks. Approaching amorphous.

Fluffy Structure.—A surface condition where the aggregates are loose, of light weight and fine texture, with no cohesion or evidence of arrangement; floury.

Granular Structure.—Aggregates varying in size to 2 centimeters in diameter, of medium consistency, and more or less subangular or rounded in shape.

Fine Granular Structure.—Aggregates under 5 millimeters diameter.

Coarse Granular Structure.—Aggregates close to maximum size.

Hardpan.—An horizon of accumulation that has been thoroughly cemented to an indurated, rock-like layer that will not soften when wet. The term hardpan is not properly applied to hard clay layers that are not cemented, nor to those layers that may seem indurated when dry, but which soften and lose their rock-like character when soaked in water. The true hardpan is cemented by materials that are not readily soluble, and is a hard layer that definitely and permanently (in nature) limits downward movement of roots and water.

Clay Pan.—An horizon of accumulation or a stratum of stiff, compact and relatively impervious clay. The clay pan is not cemented, and if immersed in water can be worked to a soft mass. Its presence may interfere with water movement or root development the same as a true hardpan. It is more difficult to overcome, for, whereas a hardpan can be shattered by explosives, the clay pan, after breaking by any means, will run together and re-form as soon as thoroughly wetted. The distinction between hardpan and clay pan is an important one in the soil classification.

Laminated Structure.—An arrangement of the soil mass in very thin plates or layers, less than 1 millimeter in thickness, lying horizontal or parallel to the soil surface.

Massive Structure.—A soil mass showing no evidence of any distinct arrangement of the soil particles. Structureless. May be found in soils of any texture.

Mealy Structure.—A crumb-like structure in which the aggregates are of soft to very soft consistency and usually less than 5 millimeters in diameter.

Nut Structure.—Compact aggregates, more or less rounded in shape, of hard to medium consistency, and from one-half to 4 centimeters in diameter.

Fine Nut Structure.—Aggregates below 1 centimeter in diameter.

Coarse Nut Structure.—Aggregates over 3 centimeters in diameter.

Plate (or platy) Structure.—An arrangement of the soil mass in plates or layers 1 to 5 millimeters or more in thickness, lying horizontal or parallel to the soil surface.

Single-Grained Structure.—An incoherent condition of the soil mass with no arrangement of the individual particles into aggregates. Structureless. Usually found in soils of coarse texture.

Structureless.—Without any discernible structure or arrangement of the soil particles into aggregates. This condition is better expressed by the terms, single-grained, massive, amorphous, etc.

Vesicular Structure.—A soil horizon or soil aggregate containing many small rounded cavities smooth on the inside as though formed by gas bubbles.

CONSISTENCE

"Soil consistence" is a term expressing the degree of cohesion of the soil particles and the resistance offered to forces tending to deform or rupture the aggregates. Consistence and structure are closely related and frequently interdependent. The terms expressing consistence and structure are distinct, however, and need not be confused or used with double meaning.

Brittle.—A soil which when dry will break with a sharp, clean fracture. If struck a sharp blow, it will shatter into cleanly broken hard fragments.

Mellow.—Soil particles or aggregates are weakly adhered in a rather porous mass, readily yielding to forces causing rupture. A consistence softer than friable. Without tendency to pack.

Plastic.—Readily deformed without rupture. Pliable but cohesive. Can be readily molded. Puttylike. This term applies to those soils in which at certain stages of moisture the grains will readily slip over each other without the mass cracking or breaking apart.

Soft.—Yielding readily to any force causing rupture or deformation. Aggregates readily crushed between fingers.

Sticky.—Applied to soils showing a decided tendency when wet to adhere to other materials and foreign objects.

Firm.—Resistant to forces tending to produce rupture or deformation. Moderately hard. Aggregates can be broken between fingers.

Friable.—Aggregates readily ruptured and crushed with application of moderate force. Easily pulverized or reduced to crumb or granular structure.

Hard.—Resistant to forces tending to cause rupture or deformation. Difficult or impossible to crush aggregate with fingers only.

Tenacious.—Soils showing a decided resistance to rupture. Soil mass adheres firmly.

The terms "sticky" and "tenacious" are often used as synonyms, but in soil usage the former is taken to refer to adhesion, the latter to cohesion. Both terms may be applicable to a soil at the same time.

Stiff.—Resistant to rupture or deformation. A soil stratum or horizon that is firm and tenacious, and tending toward imperviousness. Usually applied to condition of the soil in place and when moderately wet.

Tight.—A stratum or horizon that is compact, impervious and tenacious and usually plastic.

Tough.—Resistant to rupture. Tenacious. A stratum or horizon that can be readily bored into with the auger but which requires much force in breaking loose and pulling out the core of soil.

COMPACTNESS

Compactness is the degree of resistance offered by a soil to the penetration of a pointed instrument.

Impervious.—Highly resistant to penetration by water and usually resistant to penetration by air and plant roots. Impenetrable. In field practice the term is applied to strata or horizons that are very slowly penetrated by water and that retard or restrict root penetration.

Indurated.—(See under cementation).

Loose.—Soil particles or small aggregates are independent of each other or cohere very weakly with a maximum of pore space and a minimum resistance to forces tending to cause rupture.

Cheesy.—Having a more or less elastic character, deforming considerably without rupture, yet broken without difficulty or the application of much force. (Characteristic of certain highly colloidal soils when thoroughly wet.)

Compact.—The soil packed together in a dense, firm mass, but without any cementation. Noticeably resistant to forces tending to cause rupture or deformation. Coherent. Hard. Relative degree of compactness may be expressed by terms as slightly compact, very compact, etc.

CEMENTATION

Cementation.—A condition occurring when the soil grains or aggregates are caused to adhere firmly and are bound together by some material that acts as a cementing agent (as colloidal clay, iron or aluminum hydrates, lime carbonate, etc.).

The degree of cementation or the persistence of the cementation when the soil is wetted should be stated. Some terms indicate the permanence, as "indurated," "hard-pan," etc.

Firmly Cemented.—Cementing material of considerable strength requiring considerable force to rupture the mass. Usually breaks, with clean though irregular fractures, into hard fragments.

Indurated.—Cemented into a very hard mass which will not soften or lose its firmness when wet, and which requires much force to cause breakage. Rock-like.

Weakly Cemented.—Term applied when cementing material is not strong, and the aggregates can be readily broken into fragments with a more or less clean fracture.

Softly Cemented.—Term applied when cementing material is not strong nor evenly diffused throughout the mass. Aggregates are readily crushed, but do not break with a clean fracture.

Appendix D

(6) METHODS OF PROTECTING AGAINST DRIFTING SNOW AND OPENING SNOW BLOCKADES

F. W. Hillman, Chairman, Sub-Committee; Paul Chipman, G. B. Farlow, P. D. Fitzpatrick, J. A. Given, E. M. Smith, J. C. Wallace, F. E. Wiesner.

Last year this Committee presented a report on "Methods of Protecting Against Drifting Snow and of Removal of Snow on the Line and in Yards and Terminals" as information, with a recommendation that this subject be reassigned so that the material now contained in the Manual ("Snow Fences, Snow Sheds and Recommended Methods of Snow Removal", pages 73 to 76, inclusive, adopted 1909, 1910, 1915) might be revised in the light of the 1933 report and comments thereon. In the reassignment there was a modification made in it, as indicated in the title above, with a further requirement for collaboration with Committee XXVII—Maintenance of Way Work Equipment. Accordingly, the following report, prepared in collaboration with Committee XXVII, is offered for publication in the Manual to replace the present material referred to above.

PROTECTION AGAINST DRIFTING SNOW

Snow is carried by the wind close to the surface of the ground and is deposited in drifts whenever the velocity of the wind is reduced or eddies are formed by obstructions or by sudden changes in the configuration of the surface, such as railway cuts.

Brush, trees, buildings and other obstructions which cause snow to be deposited in drifts on tracks should be removed where economically justifiable.

Drifting of snow in shallow cuts may be prevented or alleviated by either raising the tracks and eliminating cut or reducing slopes on both sides to 4 to 1 or flatter. Other cuts may be widened to provide a place for the snow to accumulate.

Where none of these remedies are practicable or effective, consideration must be given to placing snow fences in the path of the wind so as to form artificial eddies on the windward side of the track and far enough away to cause the snow to be deposited before it reaches the track.

The location of the drift or eddy depends upon the form of the fence. A tight fence of sufficient height causes the snow to accumulate on the windward side of the fence; an open fence causes the snow to accumulate principally on the leeward side. The distance between the drift and the fence depends upon the height of the fence, the width of the openings between the solid members, the velocity of the wind and the character of the snow.

The type of snow fence and its location for the protection of a definite stretch of track depends largely upon local conditions, which may vary from year to year. These can be determined only from experience. For this reason portable snow fences are recommended generally for an initial installation.

Portable snow fences of the type shown on a following page, are frequently used. A similar fence of steel construction also is available. However, this type of fence is being replaced by the lighter slat and wire type, which can be rolled up, moved and quickly re-erected. When necessary to resist high winds, this type may be guyed with wire to bolts or stakes driven into the ground. If the location is one where the fence may have to be raised due to snow piling up, long posts should be used.

Portable fences usually are erected in the fields adjoining the right-of-way. They should be set on the windward side of the track at right angles to the prevailing winds; to provide for variations in the direction of the wind, it is sometimes necessary to set the fence in crescent form. The topography for some distance away from the track has such a bearing on the action of the wind that sections otherwise similar cannot always adequately be protected with the same type of fence set the same distance out. For ordinary conditions one line of fence is sufficient. The quantity of snow sometimes, however, requires additional lines of portable snow fences set parallel and spaced about 100 feet apart.

Where experience indicates that the right-of-way is wide enough and other local conditions permit, a snow fence of a fixed type may be used, frequently serving also as right-of-way fence.

The most generally used types of fixed fence are shown on a following page. Where the right-of-way line is 50 feet or less from the center of the nearest track, a fence with the boards laid close should be used. For greater distances, space should be provided between the boards; at a distance of 100 ft., the openings should be 50 per cent of the area of the fence. The height of fixed board fences depends upon the probable amount of snow.

Trees and shrubs properly selected for adaptability to climate, properly planted and cared for, afford an effective protection in some localities against drifting snow, and at the same time serve to improve the appearance of the right-of-way.

Stone walls may be used for snow barriers where suitable and sufficient stones for dry masonry walls are available.

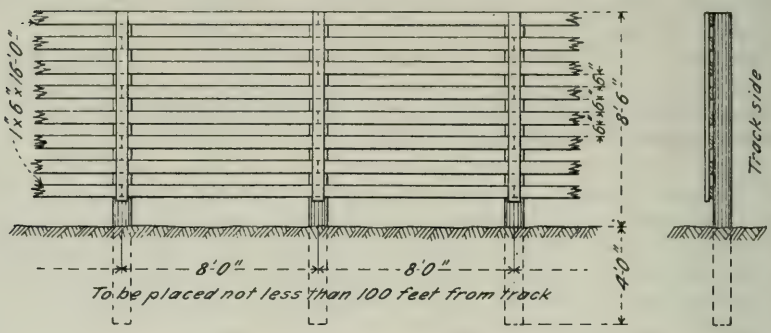
Storms differ so much in their intensity and action from year to year that it will generally be found uneconomical to build a fixed fence to afford protection against the severest storms. The fixed fence should be built as a first line defense against the average storm. Portable fences of a type which can be quickly erected should be depended on for second and third line defense, as experience demonstrates the need.

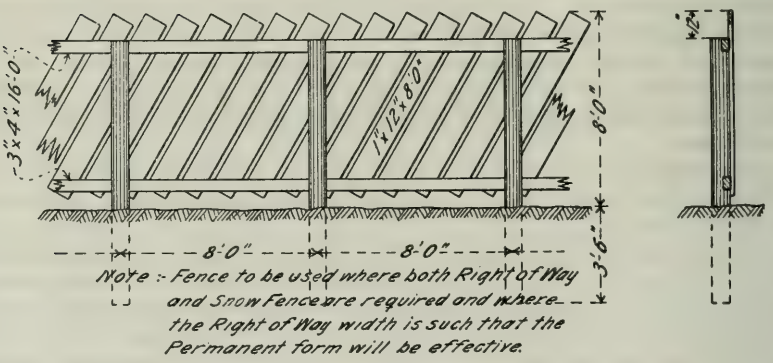
In emergencies, snow can be thrown up by hand into banks or ridges back of fixed or portable fences as an added line of defense.

In localities which require protection from mountain snow slides, snow sheds are necessary to furnish adequate protection. These are expensive to construct and maintain and should be constructed of durable materials. The railway should be so located, if practicable, as to make snow sheds unnecessary.

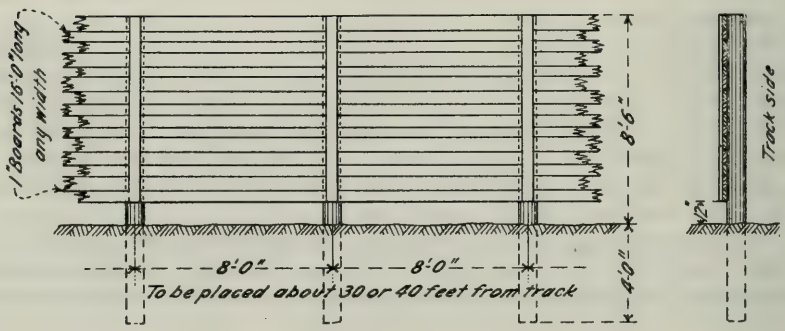
PERMANENT SNOW FENCE

Open Boarding

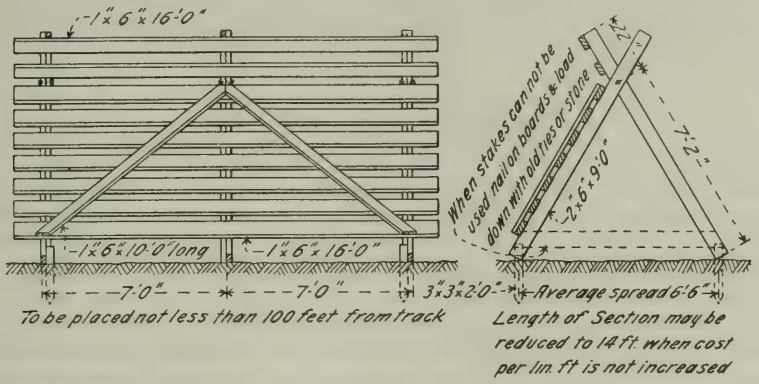


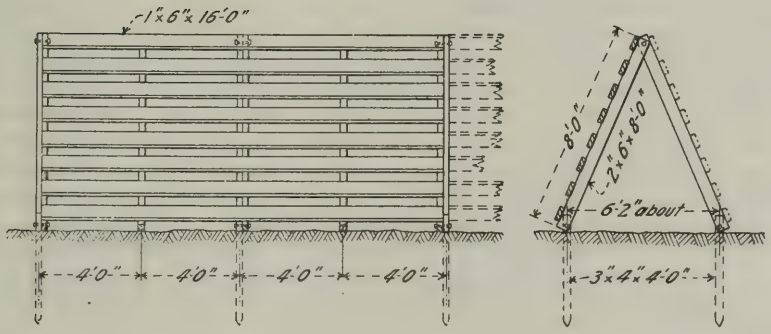


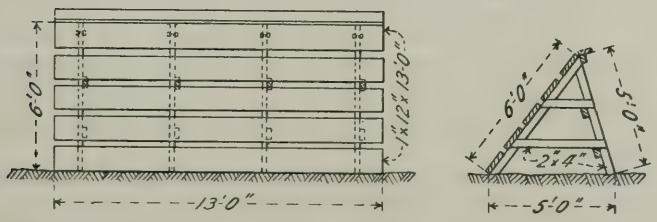
Close Boarding



PORTABLE SNOW FENCE







A

In cuts from 25 feet to 30 feet deep where it is not economical or practicable to widen the cut, timber snow sheds are sometimes constructed to advantage. In these the roof extends over entire width of cut and are designated as prairie type snow sheds. They are much lighter in construction than the heavy mountain type which are designed to resist snow slides.

OPENING SNOW BLOCKADES

General

Keeping a railway line open in territory subject to heavy snows requires watchfulness, orderliness and forethought. In the fall all snow equipment and accessories should be tested and made ready for emergency use. A general program should be formulated for stationing snow fighting equipment at vantage points, outlining a general supervisory plan, and determining methods by which men are to be secured, protected from hazards attending snow storms, fed and relieved.

Meteorological reports should be made available for general and division officers and local officers should be kept well informed of the progress of approaching storms.

It is desirable to keep ahead of storms and not let the line become blocked. To get best results it is essential that snow plows be started from terminals before the storm actually breaks and, in severe storms, additional plows despatched at such intervals as will preclude the formation of snow banks that cannot be moved with plows, possibly following up with a locomotive to pull out the plow or its engine or both if they get stalled or derailed. Prompt clearance of cuts before further snow or wind storms is quite necessary. It is the following storms which generally cause real trouble.

During severe storms, if there is difficulty in keeping the line open, consideration should be given to reducing tonnage, double heading or abandonment of trains and curtailment or complete stopping of yard switching until the storm abates and the line is opened. Stalled trains and dead locomotives add much expense, anxiety and hazard to the work of moving snow and delay opening of blockades.

No definite rule can be established for the use of flangers or plows. Much depends on the moisture content of the snow, formation of drifts and on the available clear space for snow disposal. However, the following suggestions are made as recommended practice:

On Line

Flangers should be used for the removal of snow where the depth is less than 6 inches over the top of the rail. Flanging of tracks is greatly expedited if the flanger is equipped with scoops for each direction which allow flangeways to be cleared in either direction without turning the flanger. The scoops must in all cases be equipped with lowering and raising device operated from inside of car. Flangers can frequently be used to good advantage by attaching to rear of freight train and thus avoid using an extra train and crew.

The wedge or push plow placed on the pilot of the locomotive is useful for occasional light drifts of up to two or three feet over the top of the rail.

The larger wedge or push plow should be used for removing snow up to 6 or 8 feet deep which cannot be removed by flangers or push plows on locomotive pilots. The effectiveness of these plows is greatly increased if they are equipped with adjustable side wings, which can be used for widening the opening. These plows should be equipped with a coupler on front as well as rear so as to expedite switching of cars off of sidings or yard tracks which must be cleared of snow.

Great care must be exercised in the use of plows placed on the front of loaded ballast or gondola cars to prevent the cutting edge of the plow from riding on the rail and catching at frogs, switches and crossing plank due to the weight of the snow. This can be prevented by a narrow casting placed under the plow near the cutting edge so as to ride on the rail and keep the plow up. Special consideration must be given the designing and placing of this casting if self-guarded frogs are to be encountered. There are combined flangers and plows so designed that this difficulty does not obtain.

Care must be taken in approaching drifts which snow plows will not uniformly contact and cause plow to turn over sidewise. If face of drift is frozen over the rails, it should be broken down or "faced" so that plow will engage the snow and not ride on top of it. If the plow has been stuck and pulled back, the snow may have been compacted to such an extent that it should be broken down before making another charge and possibly causing serious damage to the plow from impact with solid snow.

Ditchers with plow-shaped front make excellent snow movers. The spreader wings can be used to good advantage to widen the cut after it is opened up. Many of these ditchers are equipped with steel teeth set under front edge of the plow which are very effective in cutting up ice which may have formed between and over the rails.

Ice cutter cars have been used with great effectiveness for loosening hard snow and ice which forms in the tracks, especially in yards and on occasions in many miles of tracks. These cars are essentially a box car with end lookout windows and compressed air equipment, by means of which a lever may be moved to raise and lower a plow or V shaped steel plate 1″ thick, 6″ wide and about 4′9″ long placed below the center of the car on edge and between the running rails. To this steel plate 4″ apart and extending 6″ below its lower edge are bolted tire-steel teeth with points inclined slightly forward. Extra teeth are carried in the car. The cutter must, of course, be raised at turnouts and crossings.

Rotary snow plows are necessary for quick removal of snow where the snowfall has filled deep cuts which cannot be removed with push plow. Attempts to use them in shallow drifts not deep enough for reasonably full contact of wheel may cause the wheel to race under the light load and damage the machinery.

When operating flangers and plows over the line, the problem of keeping ice and snow out of guard rails, frogs and switches is important, particularly in locations where it is difficult for section men to get to them in severe storms. Carbide carried on the plow and placed on the ice will in a short time get sufficient moisture to form gas, which can be ignited; the heat generated will melt the ice. Casing Head gasoline, or Hydrocarbon might also be sprinkled over such places and ignited. Salt can be used also, except in electrified, automatic signal, or train control territory.

In Yards and Terminals

The method for removal of snow from yards and terminals depends upon the physical layout, the density of traffic and the amount of snow.

If snow is not very deep, possibly it is best not to remove it from tracks, except to make flangeways by hand shoveling, or with flangers, if traffic will permit, and clean out of switches by hand or snow melters. The use of the latter requires good drainage to carry away melted snow or it may freeze and cause more trouble than the snow, or heat must be great enough to evaporate water. Frequently switch engines are equipped with a perforated pipe laid across track under pilot and steam blown through it to clean away snow. If traffic is not too dense, this may be successful, but in dense traffic districts another engine added is often a nuisance. Then, too, if not judicially used, it

may be simply a case of blowing snow back over places already clean. Casing Head gasoline and Hydrocarbon sprinkled over snow and ignited is also used. Salt should not be used in electrified, automatic signal or train control districts and should be used in other districts only during that portion of winter when snow melts during the daytime and freezes at night.

In clearing yard tracks of heavier falls of snow, it is well to first pull cars off of four tracks; then run a plow down one track and follow with a spreader, pushing the snow clear of adjacent tracks; then run the spreader down the cleared tracks, repeating the operation until the snow is piled too high for further piling. Then start on the other side of the pile and repeat. In some instances, where the yard is not too wide and the snow not too heavy, the entire yard may be cleared with the spreader and picking up the snow avoided. Where this cannot be done, the piles of snow must be left to melt or loaded onto cars either by hand or machinery. With extremely heavy snow falls, the rotary plow may have to be used to open up tracks.

In cleaning snow off station platforms, where snowfall is light, hand methods are probably the cheapest. Small wooden hand push plows are effective. Use should be made of baggage trucks, on which to load and carry away snow. Snow should not be placed on tracks, as passing trains may throw it over passengers waiting on platforms. Where the snowfall is heavy, large horse-drawn scrapers are effective. A supply of sand should be on hand at stations to scatter over platforms in sleeting and freezing weather. Salt should not be used on concrete platforms.

At team yards snow can be pushed to the center or side of driveway with plows either horse-drawn or placed on automobile trucks or tractors. The snow may be left to melt or loaded onto trucks or cars by hand or machinery.

Appendix E

(9) METHODS OF PROTECTION AGAINST DRIFTING SAND

C. W. Baldridge, Chairman, Sub-Committee; Paul Chipman, G. B. Farlow, L. C. Frohman, C. T. Jackson, Roscoe Owen, E. M. Smith, H. E. Stansbury, J. B. Trenholm, J. C. Wallace.

Drifting sand, frequently called blow sand, is a source of considerable trouble and much expense to many railways as well as to highways, irrigation and other ditches, etc. Not only is the trouble from drifting sand a present one, but the sand dunes and buried lands, in many localities, and buried cities of the ancient times show that it has been a source of trouble ever since humanity began attempting to build permanent dwellings and permanent works.

The exceedingly dry and windy fall, winter and spring of 1932–33, throughout much of the western half of the United States, brought trouble from drifting sand and earth at many places not previously so affected.

The earliest correspondence on the subject, to fall into the hands of the Committee, is a letter written in 1918 by the Chief Engineer of the A. T. & S. F. Railway, carrying the following information:

> "In the earlier days (1901) we experienced trouble around Waynoka (Oklahoma) from drifting sand, mounds at times four and five feet high being deposited on the track, and at times causing delay to traffic, so much so that for sometime we maintained a trackwalker from Waynoka west, I think about seven miles, and which was in the area where the sand mounds existed and shifted considerably.
>
> "No remedy has been found, and it is necessary at times to haul out the accumulated sand by work trains, team work, with scrapers or other methods."

Another letter of interest, written in 1932, also by the Chief Engineer of the A. T. & S. F. Railway, and addressed to Everitt W. Wilson, Acting Director–General and Engineer in Chief of the Southern State Railways, for the Imperial Government of Persia, at Ahwaz, Persia, has the following information:

> "We do not have any extreme cases such as you have in Persia, and we are able to cope with this problem with sand fences and hand shoveling. Sometimes we have to use teams and scrapers to carry off the accumulation or use ditching machines. Snow fences in some cases become covered over and then it is necessary to place another fence on top of the pile or in a different location. We have experimented with planting sweet clover to cover sand, but without much success as the seed would be blown away before they could germinate. Our snow fences are usually made of old ties stuck on end, but picket fencing can be used advantageously for this purpose."

Mr. Wilson's reply throws some light on other people's troubles with blowing sand, and they are not all due to the wind:

> "Our problem is complicated by the utter lack of all vegetable life and the violence and duration of sandstorms. In some places, we shall undoubtedly be driven to use a sort of corrugated metal tunnel and let the sand blow over it. In other places, we are experimenting with steel cement casks and old oil drums filled with sand and spaced a few feet apart in a line paralleling our tracks a few hundred feet to windward. These rows of obstructions, we hope, will cause sufficient eddy currents to precipitate deposit before reaching our tracks. What we are going to do eventually to rid ourselves of this accumulation of sand remains to be seen. Wooden fences are impracticable because the nomads appropriate every bit of fuel they find, even including cross-ties at times."

Reports of special interest that have come direct to the Committee are quoted as follows:

From Mr. Kirkbride of the Southern Pacific:

> "Reference on page 885 of Camp's "Notes on Track" to standard section of roadbed on the Southern Pacific requiring protection against damage by sand storms is to a very old standard which we no longer use, as it was not effective.

"The methods which we do use for controlling sand may be classified under three subdivisions, depending on climatic conditions, as follows:

(1) Along the Pacific Ocean, in certain localities in California and Oregon, the drifting sand from the ocean is controlled by covering the sand dune areas with vegetation. This is accomplished by first planting bent or bunch grass; after this grass has developed a dense and vigorous growth and the sand areas have become still, we follow up with the planting of acacia and similar shrubs, pine and eucalyptus trees. Areas near habitations of the better order are reclaimed by planting mesembryanthemum. The successful growth of such vegetation depends on the moisture from the sea fogs and rains prevalent along the coast.

(2) In semi-arid regions where there is sufficient moisture to grow desert trees such as the athel or tamarisk, rows of such trees are planted at intervals extending out some distance from the track. These raise the air currents permitting a natural vegetation of desert grasses and brush to grow.

(3) In desert territory where the absence of sufficient moisture or other conditions makes tree and grass growth practically impossible, it is deemed best to level down the hummocks, remove all scattering brush and other obstructions such as fence posts, piles of ties, etc., thus permitting the wind to have a free sweep across the track and right-of-way. This permits the sand to move with the wind without piling up.

"Obviously, such methods of sand control require the cooperation of adjacent property owners where land is held in private holdings.

"The athel or tamarisk tree is a native of the Sahara Desert. It is a remarkably fast growing tree and one we find very serviceable in establishing wind breaks around section and station buildings. We use this tree very extensively in Southern California, Arizona and New Mexico."

From Mr. J. Haas of Division Engineer Wagner's forces, Santa Fe Railway, Amarillo, Texas:

"At MP 12 on the NT&SF (Texas) we have attempted to check drifting sand by placing a solid line of old ties on end, placing them in the ground 1½ to 2 feet and then placing additional rows on top of and behind the first row as sand drifted to the top. We have them now three ties high. This protects the track for awhile, but results in the formation of a sand dune and, of course, requires the removal of sand from time to time from the side of the track by reason of the high bank or "dune" of sand forming and this sort of protection gives only temporary relief.

"On the B&NW at MP 16 (Oklahoma) we had considerable trouble with blow sand covering our tracks several years ago. We attempted to stop it by placing old ties at the right-of-way fence, but found that this method caused the sand to drift and it was forming a rather high sand drift or dune and we removed the old ties and cut out all of the brush and obstructions from the south side of the track to the right-of-way fence and made a uniform surface of the right-of-way where the sand was giving us trouble and then placed a layer of about six inches of clay and hard dirt on the top and smoothed it down. This hard clay was placed a distance of ten feet on each side of the track to the top of the ties and we also filled the track in with it between the rails, giving this about two inches of the hard dirt, which permitted the sand to blow over and away from the track and not lodge or drift as previously. This was done in 1924, since which time we have not been bothered with blow sand on the track at that location.

"At MP 14 on the B&NW branch (Oklahoma) we have a mountain of blow sand which accumulates to a depth of 15 feet up to our tracks. This location is in a cut formed by blow sand and we have found no method of stopping or preventing it. We simply allow it to accumulate and every two years we use a caterpillar shovel and work train and load it out and dispose of it where we can along our tracks along fills. We take it out back to the right-of-way fence, about fifty feet from the track and down to a depth of about four feet below the grade.

"We have recently been experiencing trouble with sand on the track at various locations on the NT&SF between Perryton and Morse (Texas), which is caused from dry soil and high winds; the winds blow our right-of-way fence full of thistles and the soil drifts into these and drifts on and over to the rails. The only thing we have tried to do at such locations is to clean out the thistles from the fence as fast as possible and permit the sand or dirt to blow over and away from our tracks.

"My idea is, that if we can get a smooth hard surface, for 8 or 10 feet on each side of the track and in the roadbed between the ties and the rails, possibly with oil by placing sufficient to form a crust, it might permit the sand to blow away as it would not get a start to form a drift, also the sand in the immediate vicinity might be held by applying a heavy coat of waste oil to the right-of-way fence on the side where the wind prevails and which causes the blow.

Willow Mats in Highway Cut, Waynoka, Okla.

"The highway people at Waynoka, Oklahoma, have placed woven willow mats on the face of sand cuts along the paved highway south of Waynoka.

"The matting as shown, I think, is effective for location where placed on north and south highway and was placed to prevert blowing out of sand from sides of the cuts as it seems to be doing its work very effectively."

From R. C. Kline, Division Engineer, A. T. & S. F. Railway, Winslow, Arizona:

"Due to the dry season this year and the over grazing on the range at various locations, there is very little vegetation. As a result we have been troubled with blow sand at a number of new locations on this Division. In this country a wet spring starting the vegetation before April, materially reduces our drifting sand trouble."

"Methods of Protection Against Drifting Sand—Albuquerque Division—The Atchison, Topeka and Santa Fe Ry.

"The Santa Fe Railway, as located between Albuquerque and Winslow, crosses open sand flats and follows the San Jose and Rio Puerco Rivers for about 222 miles and is located on the banks of the Little Colorado, a distance of 30 miles between Holbrook and Winslow.

"The sand flats and streams are dry for about nine months in each year which exposes the dry sand which is picked up by the heavy southwest winds prevalent during the months of April, May and June.

"Many attempts were made to obtain protection from the drifting sand, none of which have been entirely effective.

"Sand Fences

"About twenty years ago a number of sand fences were constructed somewhat similar to snow fences. These failed for the following reasons:

"If the sand fence was constructed close enough to the track to prevent sand blowing across the rails, the sand soon filled up behind the fences forming a sand dune which gradually worked over towards the tracks. After the sand dune had reached the tracks, it was necessary in order to afford protection, to haul away all the sand that had accumulated behind the fences which entailed considerable expense. The tops of all these old fences have been worn away due to the action of the wind blown sand. If the sand fence is located a sufficient distance away from the track to prevent formation of dangerous sand dunes, they are too far away to prevent sand from blowing across the rails.

"As shown by photograph, where we have installed some old tie fences, you will note the accumulation of adobe and sand behind the fence. This layout, however, does not prevent the sand and adobe from accumulating between the rails on the main line. This fence is located about three miles west of Suwanee.

"At a location where we have trouble with sand just east of the Colorado River Bridge about three miles east of Winslow, an old tie sand fence was originally constructed near the right-of-way line, approximately 80 feet out from the track. After five years, sand had accumulated from this fence to the track, creating a dangerous condition which made it impossible to keep the top of the rail clear of sand during the heavy wind storms and it was necessary to move the sand accumulation with teams at considerable expense. The accumulated sand was removed to a point below the top of tie and in this way no obstruction was offered to the wind and the sand simply blows across each track, accumulates on each side of the rail, but not sufficient to cover the top of the rail. This is much less dangerous than the previous condition with the use of a sand fence. Wherever possible we have adopted this method of eliminating any obstructions above the top of rail and allow the sand to drift across the tracks, as we found that the sand does not accumulate over the top of rail with this method and as long as there is no sand on the top of rail, there is very little chance of derailment.

"Planting Trees and Shrubs

"At a location about three miles west of Joseph City where the bed of the Little Colorado is exposed adjacent to the track, the river bed being about one-quarter of a mile wide at this point, the wind blown sand was very bad. The sand trouble was practically cured for the time being by planting of cottonwood trees, shrubs, etc., which prevented the wind from picking up the sand in the river bed. We found, however, it was necessary in this free range country, to build a fence out into the river to prevent cattle, burros, horses, etc., from eating tender leaves on the young plants and trees. This method is effective but not permanent. The first time the high water in the river flows through this territory, the young trees, shrubbery and our fence will be washed away in a few minutes. The shrubbery, etc., has afforded us protection for the past two years.

"In the LeRoux Wash located about three miles west of Holbrook, the blow sand accumulates against the south side of the girders. The sand does not accumulate on the lee side of the bridge. The sand had accumulated as high as the deck timbers, entirely filling the two easterly spans and a portion of the third span of this bridge. The sand was cleaned away from the girders of this bridge with a ditcher and ten days after the work was done, the sand was as high as it was before the ditcher was used.

"The sand that we are troubled with on this Division is a very light grain blow sand which is easily washed away by the first high water."

From C. H. Purcell, State Highway Engineer of California, by T. H. Dennis, Maintenance Engineer:

"As to our experience with drifting sand:

"We have had considerable experience along this line in the Mojave and Colorado Deserts in the southeastern part of the State and in connection with sand dunes along the sea coast in the northwestern part.

"Control measures in the desert sections consist of the following:

1. Establishing the grade line of the roadway at an elevation such that the wind action will keep the paved surface free from sand.
2. Oil shoulders and slopes.
3. Cut channels through sand dunes at locations designed to retard and check the forward movement of the dunes.
4. Erect fence on the order of the lath type snow fence to catch drifting sand before it reaches the roadway.

"On the Coast section, the only control measure has been the planting of coarse species of grass and plants to retard the movement of the dunes.

"Item 1 is self-explanatory. The grade to be established is determined by observation of local conditions.

"The oil used under Item 2 was so-called light fuel oil having an asphaltic content of 40-50, or 50–60% of 80 degree penetration asphalt. The rate of application varied with the conditions, from ½ gallon per square yard of area treated to one gallon per square yard. The lighter oil gave good penetration without heating. The heavier oil must be heated to about 175 degrees F. before applying.

"The channel type of work referred to in Item 3 applies to locations where the dune encroaches in the shape of fingers. By cutting channels parallel to the roadway across these fingers, space is provided for the drifting sand and the movement is retarded thereby. The space between the fingers of the dune provides storage for sand removed from the channels. The frequency of clearing the channels depends on conditions."

From J. W. Williams, Chief Engineer of the Western Pacific Railroad:

"The Western Pacific is employing three methods of protection against drifting sand, the protection used being governed by local conditions, physical and climatical, and can be classified under the headings of 1. Sand Fences; 2. Trenches; 3. Vegetation.

"1. Sand Fences:

"(a) Lath Fence—In 1929 the Western Pacific put up one and one-half miles of sand fence in the vicinity of Bronte, Nevada, on the Smoke Creek Desert where drifting sand has given considerable trouble. The fencing material consists of 4 ft. lath, spaced 2½" apart, and held in that position by five double strands of #15 gage galvanized wire and comes in 5-rod rolls of continuous fencing. The fencing was attached to old ties removed from track after tie renewals. The cost of this fencing was 10¢ per linear foot of fence. This type of fence is giving satisfactory service and since the installation the track at this point has been free from sand.

"The Los Angeles and Salt Lake Railroad has had considerable experience with the use of this type of fence, installing same in single, double and triple lines, depending on conditions, and in some places, it has been found necessary to extend the fence higher by adding a complete section.

"(b) Snake Fence.—In 1932 sand fences were put up with old ties in the form of an old-fashioned snake fence, without being fastened together. These ties were obtained from tie renewals in the immediate vicinity of the fence job. This type of fence, although no costs are available, is very much cheaper than the lath fence described above. This fence has not been in sufficient use to permit of an opinion as to its effectiveness.

"2. Trenches:

"In 1930 the Western Pacific dug trenches as an experiment for protection work against sand being blown in the track between Salduro and Arinosa, Utah, on the Great Salt Lake Desert. Three trenches 3,000 feet long were dug parallel to the track, spaced 96 feet, 83 feet and 67 feet, respectively, from the track. At intervals of about 700 feet cross trenches were dug at right angles to the track and extending between the two outside trenches. These trenches were 24 inches wide, 30 inches deep, and can be constructed at a cost of 2¢ per linear foot of trench, under ordinary conditions of work.

"These trenches have not been in use for a sufficient length of time to definitely determine their worth. From observation, all the sand carried by small sand storms has been stopped by the first trench at the greatest distance from the track.

"This idea of trench construction as a protection was conceived from the experience of this and other roads in the manner of handling sand piled up at sand fences and other barriers. As the sand piled too high and too near the track roadbed it has been necessary to remove the sand by steam shovel or ditcher and during this operation a trench was generally dug to be later filled by the drifting sand stopped by the fence barrier. In the trench system, as employed by this road, it is the conception that the trenches will serve as a barrier and depository to the drifting sand, thus obviating the necessity of fence construction.

"3. Vegetation:

"The Western Pacific has recently planted a vegetation called 'Sea Bent Grass' on the slopes of some of its sand cuts in Nevada and Utah. This grass has been furnished by the Superintendent of Parks, San Francisco, Calif. It has been extensively used around San Francisco where hundreds of acres of sand wastes have been reclaimed with it. This grass has also been shipped to Michigan and north European countries and has done well in all instances, proving its resistance to cold climates.

"The Southern Pacific has used the Sea Bent Grass extensively near San Luis Obispo with success.

"As this Sea Bent Grass has been planted this year, there is no definite information that can be given at this time as to results obtained on our line.

"The Western Pacific, in its experimentation, is endeavoring to solve its sand drifting protection according to the local problems involved. Our problems are such that no great drifts have accumulated where fences have been used and for our particular problems fences of the type described under 1 (a) above have proven satisfactory and of

more than as a temporary barrier which would be the case where great quantities of drifting sands occur. We are very much interested in the success of the use of the Sea Bent Grass as a protection to drifting sands and believe that its extensive use can solve many problems, especially the drifting of sand in cuts."

From Division Engineer A. B. Truman, of the New Mexico Division, Santa Fe Railway:

"We have had more trouble all over the division this year on account of sand drifting on to the track than at any time during the past ten years. Between Levy and Wagon Mound we have a cut about six feet deep and 500 feet long which I believe would have drifted full had we not extended every effort possible in keeping this clean by use of the American ditcher and all of the men available in that territory.

"Just east of Deming we have experienced more or less trouble account of sand drifting on the track, but three years ago the right-of-way was entirely cleared of all the mesquite brush which had grown up on the right-of-way and the leaving of the ground clean and without any obstruction has almost entirely overcome the trouble at this point.

"We have not put up any sand fences or other obstructions in an attempt to prevent sand from drifting on the track, as in most cases our right-of-way is too narrow to permit of any arrangement of this nature."

From R. H. Baldock, State Highway Engineer of Oregon:

"We have had considerable experience with the control of blow sand along the Columbia River since 1920, by oiling and have found it a most successful way to overcome the raveling of slopes and the movement of dunes.

"Our experience indicates that a light grade fuel oil, having an asphaltic content of not over 50% with a viscosity below 35 (Saybolt Furol at 122 degrees F.) should be used. It should be applied at the rate of 0.12 to 0.20 gals. per sq. yd. In the Spring of 1933 we oiled 219,600 sq. yds. of sand slopes with an oil of about 55% asphaltic content. This oil was applied at the rate of 0.14 gals. per sq. yd. at a cost of $0.0099 per sq. yd.; divided as follows:

Cost of 30,410 gals. incl. freight	$1,255.93
Cost of Sealing	143.12
Cost of Applying (Incl. rent of eqpt.)	775.87
	$2,174.92

"The equipment used consisted of a steam boiler to heat the oil, an ordinary pressure road distributor, equipped with hose 300 ft. of 2½ inch old fire hose having a fan shaped nozzel, a small truck and ladder for climbing cut banks. The oil was heated to 175 degrees F.

"It is not desirable to apply too heavy a coating of oil as the principal advantage of oiling is that it enables weeds and grass to start in the cracks of the crust so that in many instances a dune is completely restrained by natural vegetation within a few years. It is preferable to oil early in the spring or soon after a rain while the sand is firm and not moving. The moisture is also retained to germinate seeds of any grass or weeds present. The number of re-oilings and intervals between is quite variable, depending upon how quickly vegetation can be induced to grow and whether the sand is blown in from distant sources. Stock should not be allowed to run at large over oiled spots as they soon destroy the entire crust. We have in some instances been compelled to purchase additional right-of-way so as to fence out the stock from the oiled dunes. In general it is desirable to go over the sand ground about the first or second year to re-cover the spots that were poorly oiled. In most instances this has effected a semi-permanent cure by the growth of vegetation so that we have had no further re-oilings in eight or nine years. In one place on the Columbia Highway near Dillon a large moving dune has entirely disappeared due to oiling the area which supplied the dune, so that we have been able to improve the alinement where it was originally thought necessary to by pass around the dune.

"In the coastal regions along the Coast Highway, where oiling is objectionable from aesthetic viewpoint, we have made extensive plantings of Holland grass, Huckleberry and Scotch Broom, principally on high cut slopes. The transplanted vegetation has grown fairly well, particularly the Scotch Broom, but the method is rather expensive and its

success rather hard to predict on individual cuts. Sand cuts should have a slope of from 1½ to 1 to 2 to 1 even in areas of heavy rainfall to prevent the sand displacing around the plants. Some protection can be given by windrows of brush along the slopes."

From R. C. Gowdy, Chief Engineer, Colorado and Southern Railway:

"Both the Colorado & Southern and the Fort Worth & Denver City lines, the latter being the Texas line of the system, were troubled with drifting sand to an unusual degree all last winter and spring due, I think, to two principal causes—

1. An unprecedented amount of wind storms of high velocity and duration.
2. The large amount of sod land which had been turned over and on which no crops had been planted because of the drought and winds.

"On both the Colorado & Southern and the Fort Worth & Denver City there were considerable areas of sandy territory which have always given some trouble, but I think the greater part of the trouble which we have experienced this year came from land which had either been plowed or which had been cultivated in former years and subsequently abandoned. On the Colorado & Southern trouble was experienced in spots over practically the entire length of its main line mileage from Wendover, Wyoming, to Texline, Texas, the worst place being at Sandy on the double track line between Pueblo and Walsenburg. At this point the line is in a cut some 3000 ft. in length, and constant work with ditchers, spreaders and hand labor was required to keep the line in operation. At times the southbound track was completely covered, making it necessary to abandon temporarily operation over that track. Conditions at other points were not as bad as they were at Sandy, but in places we had a great deal of trouble, requiring constant patroling of the track.

"On the Fort Worth & Denver City the trouble was confined largely to the main line between Amarillo and Texline, and to the branch line recently constructed between Childress and Pampa. On the main line the greater part of the trouble was caused by sand and soil from newly plowed or abandoned fields, and we had a good deal of the same trouble on the Childress–Pampa line, but certain parts of the latter line are located in sandy country in which we had a great deal of trouble.

"The risks resulting from drifting sands are exceedingly serious and we had on the Colorado & Southern and Fort Worth & Denver City several derailments of freight and passenger trains as a direct result, and on the branch line between Childress and Pampa, a motor car was derailed and turned over. Sand would accumulate over the rail in a few moments to such an extent that the passage of a train was exceedingly hazardous, and it was necessary to operate trains at slow speeds in territories where trouble was anticipated. As long as sand kept moving we had no trouble with it, but drifts would start from the most trivial causes, such as shrubs, poles and even tin cans. On the Colorado & Southern we had a very considerable amount of trouble due to small windrows left on the tops of light fills several years ago when a Jordan spreader was operated. Sand drifting just above the surface of the ground was obstructed by these windrows and piled up in the cut ditches and over and between the rails.

"Except on the branch line between Childress and Pampa where permanent sand fences were built when the road was constructed, we had no protection and depended largely on temporary fences built of grain doors, ties piled rail fence fashion, etc. On the Colorado & Southern considerable relief was afforded north of Denver by the use of gunny sacks wired to the right-of-way fence, which of course, made the property look exactly like the "widow woman's farm".

"Sand is being removed by means of ditching machines, clam shells, spreaders, teams, and to a limited extent, by hand. This work is now in progress and what the cost will be I am unable to state, but it will undoubtedly run into thousands of dollars. Miles of cut ditches were entirely filled up, and many culverts were either blown entirely full or their ends entirely covered. This latter situation was particularly serious on the lines of the Colorado & Southern north of Denver where we have hundreds of boxes and culverts carrying irrigation water.

"I am not prepared to make any recommendations as to methods of curing trouble of this kind, because I think that each location should have individual study. In some cases, fences parallel with the tracks will do the work, while in other cases, spur fences at an angle to the track are better, and in both methods, the distance which fences should be placed away from the tracks must be considered. As a general rule, I think that the best relief which can be gotten is to ditch cuts as wide as possible with the bottoms of the ditches 3 or 4 or even 5 feet below sub-grade, and with the sides of the

cuts given as flat a slope as possible. In other words, having the track on a fill in a cut. This method has proved effective with drifting snow and wherever we tried it with sand, it has also been effective. It has, however, the disadvantage of being an expensive method. Oiling on either side of the tracks has been tried and found to be reasonably effective, but such large areas were involved last winter and spring as to make that method impossible and impracticable."

Fort Worth and Denver City—Drift caused by tumble weeds on fence. Some sand in track.—Texas.

Colorado and Southern—Sand fences and drifts—Colorado.

From Paul Chipman, Pere Marquette Railway:

"The Pere Marquette has but a few locations where trouble is experienced from drifting sand. The worst of these is south of St. Joseph, where the right-of-way is adjacent to a narrow strip of beach. Although the tracks are 40 to 50 ft. above the beach, much trouble was experienced in the past from sand accumulating on them. Fresh sand would be deposited on the beach after each storm, which would dry out and be blown up the slope, over the shoulder and on to the tracks. A fence with tight horizontal boards was built near the top of the slope for a portion of the distance and

has proved effective. On the remainder of the distance affected, a loose crib of old ties was built near the top of the slope, its top being about 2 ft. above the track level. This was not so effective, as sand blew through the openings and part of it finally got on the track. Further, it was undermined in places by people who would cross the tracks and go down the slope to reach the beach.

"This trouble could probably be avoided by planting willows at the foot of the slope, but this is off the right-of-way and the owners of the beach are very jealous of their rights. It is hard to get willows started on the slope owing to the looseness and dryness of the sand and to its frequent disturbance by trespassers.

"At other places we have used a tight fence of old ties set on end, which has proven effective."

From Mr. Eckert of the State of Michigan, Highway Department:

"We use, for this work, cuttings of Weeping Willow (Salix babylonica) and Lombardi Poplar (Populus nigra). These cuttings were made in the early spring, and were planted as soon as the frost had entirely left the ground. The results that we obtained were entirely satisfactory, the Willow making an exceptionally large growth. I would recommend this method of handling in planting work, and would endorse the use of the two above named varieties of plant."

From E. R. Lewis, Michigan Central:

"At Michigan City, the Northern Indiana Public Service Co. made a lawn and driveways and erected buildings on the sand dune site after leveling the dune, in which excavating they dug up three lines of fence we had placed at successive elevations. Sand fence not only is a temporary measure, but it tends to collect and heighten the sand and so make the matter worse.

"The only effective remedy I know is to get some grass or vine started which will spread and hold the sand from drifting. It is advisable to explore the immediate neighborhood and select if possible a perennial low growing, quick spreading plant for this use.

"In 1914 the structure carrying the DSS&A Ry. track over the track of the CStPM&O near Rockmont, Wisconsin, was replaced, involving a considerable lift in the approach embankments which was made with fine sand from Lake Nebagamon. The sand fill extended for about 3000 feet on the East and a somewhat less distance on the West. Horse tail probably grew in the sand pit and was picked up by the steam shovel. Without other planting, it half covered one slope during the first year. At the end of the second year both slopes were completely covered. Horse tail, equisetum equisetaceae, is a six inch joint grass which is indigenous to our eastern, western and northwestern states. Its roots spread horizontally, and with great rapidity yet they are astonishingly strong and fibrous, throwing out new plants at intervals of a few inches. The wide branching fine joint grass is the sterile plant. The fertile plant is a single thicker jointed stem without branches but bearing a terminal close fertile head. Horse tail is non-flowering, thrives in sand, cinders and otherwise bare soil. Sweet clover, wild morning glory, wild sweet pea and various other plants are of some value for slope planting. The problem is to get vegetation started before the drifting sand chokes it. I think sufficient shelter can be found about almost any sand dune to start vegetation and I would expect equisetum to grow anywhere in the Central States. I believe there are cases where it has been found necessary to build sheds over the tracks on account of drifting sand."

J. E. Willoughby, Chief Engineer of the Atlantic Coast Line Railroad, advises that on the A.C.L. there has been some trouble experienced due to sand ballast blowing away on the line between Haines City and Sebring, Florida, which traverses a ridge of sandy hills. The embankments of sand and the cuts through sand were the location of some trouble due to sand drifting almost to the top of the rail on one side of the track, while on the other side the sand ballast would scour from around the head of the tie leaving the end of the tie free. It was also found that on sand embankments the sand shoulder on one side would be almost entirely blown away with a corresponding accumulation of sand on the opposite side. This threat to the safety of the track was partly relieved by planting Bermuda grass along the slopes of the fills and in the track,

but it was not until the A.C.L. replaced the sand ballast with crushed stone and placed on the slopes of the fills a material containing clay that the difficulty was overcome. Since the beginning of the mining of soft limestone in Florida for highway purposes, the A.C.L. has been able to procure from the mines along its lines the clay over-burden and by spreading this clay over-burden on the slopes of the sand fills a further stability has been obtained.

From L. W. Colby, Sectional Engineer of the Central Cordoba Railway, Argentine Republic, we have received the following article together with authorization for its use through the cooperation of its author, C. N. Williamson, Chief Engineer of the Buenos Aires Pacific Railway, an English Company of some 3,000 miles of broad gage track (5′–6″):

SAND DUNES

Practical Method of Dealing With Them

"Dunes or sand drifts, formed by wind action, are universal in their occurrence as they exist in nearly every country in the world.

"They have two origins which might be classified as maritime and mediterranean.

"We will treat in this short article with the latter kind as it is these that interest us most, being prevalent in the Pampa regions, and we refer more especially to those in the Southern part of the Provinces of Cordoba and San Luis, crossed by the Buenos Aires Pacific Railway.

"In these regions there are great dunes already formed, which, due to the considerable height to which they have attained (10 to 12 metres) have become fixed, the outer ones being covered with natural growth of vegetation and the inner ones, that remain bare, offering no menace.

"In these dunes of vast extent and whose formation possibly dates back for more than half a century, great lakes have formed due to the continuous action of the wind that has scoured all movable matter down to the impervious bottom.

"These, however, are not the dunes which particularly interest us, but those of more recent formation.

"Undoubtedly all sand dunes have their origin on some bare patch, however small, that has lacked vegetation, as happens in the vicinity of cattle troughs, road gates and cattle yards, and also in over-stocked paddocks.

"If immediate steps are not taken to cover the bare patches with grass, straw, weeds, etc., the wind begins to burrow into them, the sand scoured from the hollow advances and we have the dune in its first or creeping stage, so much feared for its rapidity of advance and its devastating effects upon vegetation.

"If not attacked and stabilized, in a very short time it will increase in height and arrive at the second stage with its humps and hollows well defined.

"It is practically impossible to establish hard and fast rules to be observed in fighting the dunes, and each must be treated according to its form, height, etc., but nevertheless, the following procedure may be recommended.

"The first and essential measure is to fence in the drift to avoid the entrance of stock.

"Low or creeping dunes of recent formation may, as a rule, be checked by the sowing of oats, or for preference, rye when opportune; if small ridges exist, by covering these with straw, weeds, grass or any other adequate material disposable. This procedure was adopted in the South of Cordoba and San Luis during the last drought we suffered, with the best results.

"With regard to dunes already formed, the planting of Cana de Castilla (Arundo donax) is very effective. The canes are increased and multiplied by means of their rhizomas, it being possible to divide each tuft into a great many parts. The most propitious time for this is the end of winter as the canes then sprout rapidly and do not require the attention that would be necessary to avoid uncovering if they were planted at the beginning of or during winter.

"This class of cane has decided advantages over other vegetable binders due to rapid growth, drought resistance, immunity from the attacks from the "bicho de cesto" (basket worm) and ants, and the fact that it is not favored by the locust. Its reproduction is so rapid that in two or three years from the time of planting extraction may be carried out without affecting the plantation in the least degree.

"The canes may be cut at two years of growth and among the many uses to which they can be put we may mention the following: Covering bare patches of camp, making fences for seed-beds and gardens, fowl houses, shelters for stock, etc.

"The cane roots weigh on an average 300 kilos per cubic metre, approximately 1000 kilos being required to plant an hectarea, lines 5 metres apart and 1 metre between plants. The planting is extremely simple and requires no special knowledge nor great care except to avoid the uncovering of the rhizomas during the first few months.

Planting of Castilian Canes

"If the dune to be 'killed' is of small area it can be completely planted with the canes, the lines being 5 metres apart and the plants 1 metre apart on the lines, the direction of these being generally from S.E. to N.W., or perpendicular to the prevailing winds.

"Where the dunes are extensive and total planting is not feasible the following method may be adopted:

"First, plant five lines of canes completely round the dune and then, from S.E. to N.W. (approximately) every 250 or 300 metre plant 10 lines (5 metres apart).

"The first summer the dune will appear to leave something to be desired but during the second the luxurious growth will attain to a height of from 5 to 6 metres. It is at this point that the beneficial effects of the planting begin to be appreciable, the canes forming an admirable windscreen and the mounds of sand between the transverse rows begin to level up.

"We now arrive at that period when the definite killing of the dune should take place and this is done by sowing the unplanted spaces, 250 to 300 metres wide between the rows, with rye.

"In the low-lands or valleys this operation can be easily effected by means of the seed drill, it not being necessary to cover the sown area with grass, weeds, etc., but on the rising grounds it will be necessary to broadcast the seed and cover with grass, straw or the cut canes laid over and secured with stakes and wire.

"Given the slightest rainfall, the dune may be considered as killed, due to the protection afforded by the growing canes, real parapets that impede the scouring action of the wind.

"The dune, being now definitely conquered, might be used for forestry purposes which, while beautifying the region, would also in time lead to positive results, but it would not be prudent to utilize it for pasturage due to the instability of the underlying sand.

"In order that these plantations might be resistant they should be closely planted, and a convenient distance between trees would be that of not less than 2 to 2½ metres.

"The trees which, in these regions, have given the most satisfactory results are Italian, Californian and Canadian poplars, white acacia (Robinia), black acacia (Gleditschia) and also the ash (Fraxinus Excelsior) which is of rapid growth and possesses the advantage of immunity from the attacks of locusts.

"The alternative to using the conquered dunes for forestry purposes would be to sow down a mixture of rye and alfalfa which would be permanent, and could be cut and baled.

"These procedures have been tried by the Buenos Aires Pacific Railway on a live dune of 350 hectareas in formation with hummocks from 7 to 8 metres in height. This dune is now completely dominated and carries more than 500,000 trees, principally those already mentioned, besides, to a smaller degree, pines, cypress, white cedar, etc.

"These trees, almost without exception, have been raised in the nursery on the same dune.

"In spite of the drought of last year and the serious invasion of locusts, the plantations are in perfect condition.

"During the last few years sand dunes have also been attacked by means of plantations of Italian poplars on the system of the Agricultural Engineer, Sr. A. Miroli. The system consists of the planting of scions or stakes specially prepared and placed at a distance of 1 metre from each other in all directions, 10,000 stakes to the hectarea.

"The results obtained have been excellent, and even though the initial cost and maintenance for the first few years may be high, it will be more than compensated by the sale of trees, say at 10 to 12 years from time of planting.

"Among the countless uses to which Italian poplar wood may be put are the following: Paper paste, packing cases, toys, office utensils, wooden matches, charcoal (carbon de Belloc), etc., etc."

From L. C. Frohman of the Florida East Coast:

"On the Florida East Coast Railway we do not have the problem of the control of drifting sands, though approximately 75% of our road mileage is on sand embankment, or through sand cuts. Fortunately Florida is in an area of heavy annual precipitation and where the growth of natural vegetation starts very quickly and continues at a very rapid rate. On green sand embankments, or in sand ballast where the natural growth has not yet started, some minor difficulty is experienced due to "blows"—but these are never very extensive, nor serious. Usually before a "blow" can attain any important proportions the sand is heavily saturated by rainfall and periods between rains are not normally very lengthy.

"Along the Atlantic Coast there is practically a continuous 'barrier' of sand dunes adjacent to the beach. The sand in these dunes is the ordinary beach sand of fine grains, which are well rounded by abrasion due to constant movement under the action of winds and water. Normally these dunes do not 'creep' due to the almost continuous saturated condition, or condition of light moisture, for as stated this is a territory of heavy rainfall which is well distributed throughout most of the year. It requires a very stiff wind to create any appreciable disturbance of the sands when damp, or when saturated. While we have practically constant breezes, they are not stiff and, therefore, the rapid natural growth of sea grass and other native growths quickly starts on the surface of the sand. While this does not entirely cover the entire surface, there is relatively little disturbance of the exposed patches due to wind action because of the generally moist condition.

"Occasionally an area of 'creeping' sand is found, though I have no explanation to offer for this action in the midst of stationary dunes of the same sands. A small area of the 'creeping' sands is found along the ocean shore highway about 20 miles north of St. Augustine and extending for some miles northwardly. I am attaching a series of photographic prints showing the conditions in this territory, where the State Road Department has made some attempt to control, or retard, the movement of the sands by the construction of sand fences, consisting of vertical pickets on wire strands. I am referring to this and sending this information merely as an example of the difficulty of attempting to control the movement of these sands by artificial barriers. It will be noted that, in locations where there is a heavy growth of palm trees, other trees and thick, dense underbrush, the 'creeping' sands have sifted through the vegetation and gradually engulfed these natural barriers, which in some locations are more than 25′ high. At numerous spots along this territory the white sands of the engulfing dunes can be seen through the heavy growth of trees and brush. Where it has started nothing seems to stop it, as for some reason the natural surface growths of sea grass do not seem to progress, or spread, rapidly enough to prevent scour and wherever there is scour the sand is moving. It will be noted that the drift fences do not stop the sand. The sand drifted between the pickets and continued on the lee side of the fence. With a solid barrier it builds up against the barrier until it reaches the top and then proceeds to build beyond the barrier.

"I can offer no explanation for this action in the locations illustrated, as, under apparently identical conditions of sand and natural growth within a few miles of the locations illustrated, there is no movement of the dunes."

Florida East Coast—Dunes drifted up around trees to bottom of fronds. Highway in foreground. Note buried fence erected about 1930.

Dunes forming, fence almost buried, trees partially buried. Highway at this point has been covered and cleaned several times.

Dune has engulfed scrub vegetation and is beginning to engulf highway, despite drift fence.

Drifting sand plunging through heavy, tangled growth of trees and brush and engulfs all growth.

From R. H. Chapman, Chief Engineer of the State Railways of South Australia, we have received a copy of a law enacted in that state in 1923, which requires the owners of land from which sand blows as a result of its being "cleared, fallowed, burnt over, cultivated, or grazed, to protect against such blowing of sand by some of the following means as directed by the Minister—

"(a) Plant such land with Marram or other grass or plants;
"(b) Brush the land or cover the land with seaweed or other substance; or
"(c) Do any other thing prescribed, or may do some or all of these things."

Mr. Chapman also sent the following information as to the practices of that country in the protection against drifting sand:

"The areas in which sand drift occurs in South Australia may be divided into 3 classes as follows:

(A) Old established agricultural areas where the drift consists mainly of fallowed ground.
(B) Mallee country i. e. sandy country which in its natural condition carries a short stunted scrub known as Mallee. The drift here is caused by the clearing of this scrub.
(C) Salt bush country i. e. pastoral country where the rainfall is less than 10″ per annum and where the drift is due to absence of natural vegetation.

"In areas belonging to class A drift has been checked in a number of ways—

1. Brush wood fences have been built. These are not an unqualified success as they soon become buried.
2. Planting of grasses such as Ice plant and Marrom grass.
3. Planting of bamboos.

"Of these the bamboos are the most successful and the best results have been obtained by planting 4 or 5 rows about 15 to 20 feet apart across the drift.

"In areas belonging to Class B the only successful method of dealing with drift has been to limit the amount of land cultivated by leaving strips of uncleared scrub or by prohibiting the cultivation of a boundary strip on each block. This prohibition is enforced by the Sand Drifts Act.

"In areas belonging to Class C it is impossible to stop the drift. All obstructions are removed from the path of the drift so as to allow it to pass over the line. For this purpose fences are removed and cuttings are battered back to a slope of 1 in 5. Of course in this class of country the cuttings are nearly always shallow and permit of this being done.

"Where the above methods are not successful we are compelled to use work trains or horses and scoops to keep the track clear. The authorities controlling the highways of this state also use the above methods."

From H. Duncombe Bindley, Chief Engineer of the Sudan Railways, British Sudan, East Africa:

"The notes will give you some idea of the extent to which we are troubled but I fear that positive results for prevention are meagre, to say the least of it. For one thing we are subject to winds from different directions and partly on this account have been chary about the adoption of structures resembling snow fences as one day's heavy wind from the opposite direction might easily wipe out any good done during months of slow attrition.

SAND ON LINE

Sand Dunes

"Drift Sand and Sand Dunes affect the railway in several ways. Drift sand accumulates on the track, in bridge openings and against houses and buildings. That on the track requires immediate removal to allow for the passage of trains. That in bridge openings requires removal just before and during the rainy season—from the middle of July to the end of September. That against houses and buildings requires removal annually or monthly according to the rate of accumulation.

"Sand Dunes, where they exist, are more troublesome to deal with as their movements are spasmodic, depending upon the frequency of wind storms or upon wind of a sufficient velocity to cause movement of the sand particles.

Both drift sand and sand dunes have been the subjects of correspondence and theories and experiments but the large construction programmes and discontinuity in District Officials during the last 10 years has resulted in a lack of definite results of any value from such experiments as have been carried out.

"Apart from clearances of sand from the track carried out by the section maintenance gangs there have been parties employed on Abu Hamed District for the removal of sand from houses and buildings and from places where the track is in cuttings, amounting to some £E350 per annum on an average.

"Between 1920 and 1927 considerable movement of the sand dunes occurred at times of strong wind storms and train delays were not uncommon. The length affected was divided into the following sections:—

(a) Covered with sand with slightest wind.
(b) Covered with sand with very strong or continuous wind.
(c) Clear of sand.

"Sand clearing parties with telephone communication were and still are established at Kilometres 415 and 445.

"At the end of 1927 the patrol orders were revised to allow of more latitude in the despatch of trains under conditions of (1) wind of less than 4 hours duration and (2) wind of more than 4 hours duration.

"Following on an article in the Geographical Journal of September 1927 and to further previous experiments carried out on similar lines arrangements were made for the District Engineer, Atbara District, to carry out trials with the erection of a line of sleepers along the crest of a dune. As the sand was removed by wind action and the sleepers fell down, they were to be re-erected in the same troughs that formed. On another dune experiments were to be tried out with erecting sleepers rather closer together than in the first experiment so that the areas denuded round each sleeper should over-lap. The sleepers were to be re-erected as they fell over.

"It was thought that dunes so treated might possibly only move forward to some other site, but that in order for them to reform it would appear that some obstruction, either obviously apparent or due to the formation of the ground, must be present.

"It was hoped that if the experiment proved so successful as to cause the entire removal of a dune the reason for its initial formation on the site might become evident.

"Unfortunately owing to the large amount of new works being carried out at that time and to several unavoidable changes of engineers on the district the experiments were never carried out to finality and no definite results were obtained.

"In July, 1929 the sand belt at Kilom 445 had increased and the patrol length on account of sand had to be extended to Kilom 438; also a new danger area had formed at Kilom 427 to 428 and an additional sand party had to be established there. The formation of these additional dunes close to the line was attributed to tufts of grass being allowed to grow up, and steps were taken to have all possible tufts adjacent to the line removed.

"In October of that year the dunes that had formed at Kilom 428 had disappeared and the sand party was disbanded. No further trouble has occurred at Kilom 428 nor between 438 and 444 since that year. The site of these dunes was inspected this year and only two small dunes were present between Kilom 427 and 428, and these were some little distance from the railway line.

"One of the dunes at Kilom 444 has moved some 50 to 60 feet towards the railway line this year under the influence of the South winds.

"There is no doubt though that during the last few years sand accumulation on the line has diminished considerably and now that construction work has drawn to a close on account of the world depression in trade it would appear to be an opportune time to consider very carefully the possibility of adopting some means of dealing with these dunes.

"As stated previously the results of experiments made in this country are meagre and it would appear that before we can come to any satisfactory solution of the problem of how to cope with the drift sand and sand dunes, and thereby eliminate the annual cost of sand clearing and patrolling parties, we shall have to carry out some extensive and varied trials of different methods.

"The sand problem confronts railway men in North and South America, Australia and Egypt but although some remedial measures have been adopted with varying success the whole problem is so largely dependent upon local conditions that it is only by trial and error that the most effective measures for any one country, or any one locality, can be discovered.

"Attached are copies and summaries of such information as I have been able to gather together on the subject of sand dunes and their treatment."

Enclosed with Mr. Bindley's letter were the following articles quoted from other authorities:

"W. S. Barclay writing in the Geographical Journal of January, 1917 describes the sand dunes of the Pampa del Sacramento in Peru.

"The general direction of the wind is from the northwest, being caused by radiation from the desert surface and the consequent inrush of cooler air from the Pacific. It blows at about 20 miles an hour, and the sand which it releases travels at about 2 miles an hour on the hard flat surface between the ridges. The wind starts as soon as the desert warms up and increases in violence with the rising temperature, attaining its maximum force between 2 p. m. and sunset.

"The dunes take a typical half-moon shape and proceed in sequence south-east across the Pampa until they reach some large obstacle or abrupt change of level. If the barrier is negotiable they adapt themselves to cross it, the dune projecting itself into the easiest passes and elongating up to the limit of its sand-mass. Once the obstacle is crossed, the vanguard of the dunes marks time until the rear catches up, forms once more into a half-moon shape and proceeds on its way. These dunes often attain a considerable size, measuring up to 50 yards between the points of the horns.

Pebble Cure:

"Platelayers and other railway men whose duties necessitate watching them state that the dunes rate of march is about 100 yards per annum. The dunes occasionally advance over or threaten the railway line and the method adopted of avoiding the threatened obstruction is simple but efficient.

"Men go out with long handled spades and a wheelbarrow and collect loose pebbles and grit from the surface of the Pampa. This they scatter in a tin layer over the back of the dune. The pebbles arrest the action of the ripples and so interfere with the even circulation of the sand particles, which is apparently as essential to the progress of the dune as the circulation of blood to a human being. Very shortly the dune assumes a lopsided shape, sagging where the debris has been cast upon it and offering, instead of a well rounded back, a breach to the action of the wind. The process of disintegration is fairly rapid, and at the end nothing is left on the Pampa except the original wheelbarrow loads of grit and pebbles. Generally speaking the smoother the surface of the Pampa and the higher the wind, the larger and more perfect becomes the dune."

Extract From an Article in the Geographical Journal of September, 1927

"Much has been written about eddies in connection with dune-formation. The only observations I have made in this connection have been when endeavoring to place temporary marks on dunes to form survey points; and the observation seem to show that if eddies are artificially created at the top of a dune, a rapid lowering of the dune-crest results. At first I used to thrust a walking stick or ranging rod some 2 or 3 feet into the dune-crest. The stick or rod, though quite firmly fixed at first, was always found after a few hours lying half way down the dune-slope. The same thing happened with tripods firmly pressed down into the crest. When I was carrying out a little triangulation to determine the position of Rohlf's cairn at Regenfeld in 1924, I had occasion to place a mark on a high dune, and I used an empty 4-gallon petrol tin filled with sand, bedding it well into the dune; but the next day it had disappeared from the crest, and was found, as the other things had been, halfway down the slope. These observations remind me of Mr. Barclay's description of the method of dealing with sand-accumulations in the Peruvian Desert, where, as soon as dunes appear and threaten to obstruct a railway, the local inhabitants turn out and scatter pebbles and stones on the dunes, and very soon the dunes are gone, having been carried away owing to eddies produced by the wind around the stones. This device for removing incipient dunes might, I think, be tried along the Kharga Railway, where the screens put up at Mr.

Harding–King's suggestion have not been entirely successful in preventing the encroachment of sand on the line. I am the more disposed to think an experiment of this kind might succeed, because I have noticed that at the gap in the Ramak Dunes (discovered by Col. Partridge and known during the war as "Partridge Gap") there are great lumps, of silicified wood, which may have led to the gap being formed."

From the Railways in the Eastern part of the United States of America, several letters were received, but in all cases, the troubles from drifting sand were reported as of so little moment, that they can be taken care of by planting of vegetation or by fences.

From the Canadian Pacific Railway, reports were received, but the practices are confined to the erection of fences where trees cannot be grown, therefore, no copy of the reports is given here.

From Germany, the Committee received a letter from Dr. Buchholz who advised that so little sandy country exists there, that any drifting of sand is stopped by the planting of vegetation of some suitable sort.

From Russia, however, we received a letter and report, written by Professor Serge Kareischa, of considerable interest, which reads as follows:

"Methods of protection against drifting sand on the railroads of the Union of Soviet Republic.

"On the railroads of the Soviet Republic, only three roads are obliged to protect their lines from drifting sand. Such lines are—

"(1) The line from Krasmovodsk to Taschkent where the line passes through the desert, Cara Crum, on the length of 160 kilometers.

"(2) The Astrakham line of the Riason Ouralsk Railroad.

"(3) The line of the Transcaucasus railroad near Baku.

"For each line methods of protection against drifting sand must be different, according to the local conditions. During the construction of the Transkaspian line of the Central Asia Railroad, works on sandy sections (Cara Crum) were effected without paying attention to the action of drifting sands because the pernicious action of drifting sands was then unknown.

"The embankments and cuttings had the same cross-sections as on normal soils. The embankments having the width of 4.70 meters (15 ft. 5.0 inches) and the cuttings the width of 8.50 meters (27 feet, 10.6 inches). Very soon it was found that the slopes of embankments and cuttings were blown out by the wind and they were being destroyed. To prevent such results, the Maintenance of Way administration began to cover the slopes of embankments and cuttings with a layer of clay and to protect the tops of slopes by means of brush of Saksaul, a kind of tree growing in the sandy desert.

"Except for the blowing out of the slopes, the cuttings were very often fouled with sand blown in from one or the other side of the line.

"To protect cuttings from sand accumulations, they were widened to 9.6 meters (31 ft., 5.9 inches) and their slopes were made less steep.

"The information given above concerns sections where the sand is partly covered by Saksaul.

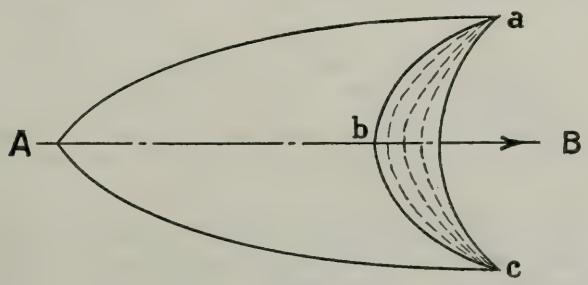


Fig. 1.

"Much more difficult is the protection against drifting sand in the form of moving hillocks called barchans. By the name of "Barchans" is meant moving hillocks of drift sands displaced from the sandy soil drifted upon the right-of-way and tracks of the railroad.

"The barchans form on the plan of a horse shoe (See Fig. 1) and dispose themselves parallel to the direction of the dominating winds. From the windward side, the slopes of the barchans are of devious pitches but they are steep on the opposite side.

"The movement of a barchan is that the rib a.b.c. moves forward with its steep sloping face. When the wind is strong, the barchans move forward quickly and the sand is moving in the air in clouds.

"When the barchans reach the roadway of the railroad, they continue their advance if they are higher than the formation, but if their height is the same as the height of the formation, the barchans stop and do not move further. Therefore, the top of the formation (the roadbed) must be higher than that of the barchans.

"By making the embankments higher than the barchans, they will be protected, or free from, the accumulation of sand upon them.

"The barchans are less pernicious for the cuttings if the cuts are broad, and the accumulations of sand are conveyed out by work trains. But the best way for protecting lines from drifting sand consists in creating of broad bands of plantations on both sides of a line.

"On the Central Asia Railroad, instructions as to methods of protection against drifting sands have been issued as follows:

"Instructions for the protection against drifting sands—

"(1) Great attention must be paid to the propagation and cultivation of plantations on the band of expropriation, particularly on sections with sandy soil or drifting sands.

"(2) In places where the track has been already troubled with sand drifts, if the track is not sufficiently protected with sand sheds, and where the roadbed is not high, and the soil is sandy, all plantations on both sides of the track must be abolished for the width of not less than 6 meters, and when the sand drifts very badly, for the width of 20 meters from the centerline of track.

"(3) The slopes of embankments and cuttings must be smooth and clean.

"(4) The gaps between the bottoms of the rails and the top of the ballast must be kept free so that the sand can pass without accumulating.

"(5) In clearing away the sand accumulations, the sand must be thrown from the track in the direction in which the prevailing winds blow.

"(6) In clearing away accumulated sand, care must be exercised to avoid the removal of the clay covering which has been placed to aid in the free movement of the sand.

"(7) The accumulation of sand heaps or other obstructions along the sides of the tracks must not be permitted because they help the formation of drifts on the track.

"(8) If the sand is brought to the line from a considerable distance, the formation of drifts at the distance of 15 to 20 meters from the track is advantageous because when such accumulations have reached a sufficient height, sand sheds may be based on their tops.

"(9) In places where the track is often deeply covered with drifted sand, ramparts must be formed at a distance of from 15 to 40 meters from the axis of the road. The height of such ramparts must not be higher than sand hillocks near the line. Generally, the height of the ramparts may be from 2 to 4 meters and rarely 6 meters.

"(10) Such ramparts can be constructed by placing along the line, dense sand sheds or sand enclosures of boards, branches of saksaul or cane.

"(11) Dense sheds or enclosures repulse the sand approaching them and to some extent cause it to drive along the sheds and partly to accumulate it on the side from which the wind is blowing.

"(12) Sheds and enclosures, not dense but with openings, do not repulse the sand well and do not cause it to be carried along the shed, but such sheds accumulate much sand until the drift becomes as high as the shed.

"(13) Dense sheds must be located not closer than from 20 to 30 meters from the centerline of the track or tracks depending upon the amount of sand which may accumulate. The end of the sheds nearest to the dominant winds may be turned toward the track to not closer than 16 meters from the centerline. The other end of the row must be turned from the track to 30 or 40 meters.

"(14) Sheds and enclosures not dense but with openings must be located not closer than 30 to 40 meters from the axis of the line and the ends must be turned to the track for a distance of not less than 20 meters at the windward end and from the track from 30 to 50 meters at the leeward end.

"(15) Before a rampart is formed of the necessary height for the protection of the line from sand accumulations, sheds and enclosures may be formed from most simple and cheap construction.

"(16) When a rampart of sufficient height to protect the track from drifting sand has accumulated along the line, dense sheds or enclosures for the protection of the track from sand and for deflections of sand along the rampart must be erected along the top. If dense sheds cannot be constructed, open sheds may be used but their effect will not be so good.

"(17) Before the dense sheds are completely filled with sand, they must be raised and reset on the top of the rampart (or drift) already accumulated.

"(18) If a shed is overthrown by the wind, it must be properly re-erected on top of the rampart.

"(19) When the top of the drift reaches the height of the shed, the shed must be placed further from the track.

"(20) If it is impossible to re-use the old shed, a new one must be erected at a greater distance from the track.

"(21) Where sand drifts badly, both slopes of the ramparts must not be covered with plantations. In such locations, the sheds should be so placed as to deflect the sand and accumulate drifts.

"(22) When the hillocks of dense sand are formed on both sides of the line, and their bases approach the roadway, dense sheds or enclosures must be erected on the tops of the hillocks.

"(23) If a sand drift approaches very near the roadway and continues to increase, a second row of sheds must be placed at a greater distance from the line.

"(24) For lines subject to the drifting of sand, a careful study should be made of all winds, both the dominating and secondary, as to their duration, force and directions in reference to the axis, or centerline, of the track.

"(25) The observations about winds must be made each day at the 7th, 13th and 21st hours."

"In 1912, the Russian Geographical Society established a scientific investigation station for studying the movement of drifting sand in the desert of Cara Crum on the Central Asia Railroad, Professor Doubinsky was appointed as director of this station.

"The observations of several years have indicated that the movements of drifting sands in the desert of Cara Crum proceed as indicated below.

"The drifting sands of the desert consist of moving rows of sand ramparts with gentle slopes on the windward side and steep slopes on the leeward side. By action of the wind, the sands from the non-steep slopes are moved onto the steep slopes, and in this way, the rampart moves gradually and extremely slowly, in the direction which the wind blows.

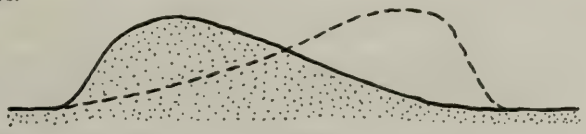


Fig. 2

Fig. 3

"One-half of the year, the winds are blowing in one direction and during the other half, they blow in the opposite direction, so the barchans change their form. That means that their bases rest nearly the same place, but their tops make a movement for half a year in one direction and the other half of the year in the other direction and their slopes change their steepness as indicated in Fig. 2."

"Thanks to this fact, the protection of the line from sand can be organized in such a manner that the ramparts (or drifts) can be made to leave the track in the valley between the adjacent drifts. After this is accomplished, the ramparts must be covered with plantation which will protect the line from further sand accumulations. (See Fig. 3)."

"On the Astrakhan line of the Riasan Ouralsk Railroad, experience has shown that the best way to protect against drifting sand is the setting along the line, at a distance of 40 meters, of rows of sheds firmly planted in the sand. If it becomes necessary to set several rows of sheds, the nearest to the track must be at least 10 meters distant. In places where sand ramparts existed along the line, the sheds were set on top of the ramparts. Cuttings when they are widened suffer less from sand accumulations than do the embankments. Even when the line is protected with sheds, sand, driven by the winds, from the slopes of embankments, form accumulations on the track.

"This evil was annulled by covering the slopes of embankments by plantations of local grass, Ayropyrum arenarium, also a Kali, and covering the slopes with branches of trees, brushwood, etc., often the slopes are covered flatly by snow sheds."

From J. M. Ashworth, Chief Engineer of the Victorian Railway of Australia:

Sand Drift in Mallee

"Prior to 1925 little trouble was caused by sand on the Mallee railway tracks. Since that date, however, the menace has steadily grown and, subject to seasonal modification, must continue to increase until general action is taken over the whole area of the Mallee.

"Inquiry has been made regarding methods and experiences of other Departments and the Government Meteorologist and the Curator of Botanical Gardens have been consulted.

"The State Rivers & Water Supply Commission, it is understood, are endeavoring to have a protective belt of scrub reserved along their channels and to have legislation enacted to prohibit summer fallowing within three (3) chains of their channel reserves.

"In 1923 an Act of Parliament was passed allowing the sale of reserves previously set aside to act as windbreaks in Mallee districts.

"Tracks now affected or likely to be in the near future are: Yaapeet line, Panac line (portion only), Donald to Red Cliffs, Ouyen to Walpeup, Dumosa to Kulwin, Meatian to Manangatang, Swan Hill to Natya.

The Chief Causes of the Trouble are:

(a) The denudation of the natural scrub and vegetation account cultivation of the land and the subsequent disintegration of all vegetable binding matter in the soil.

(b) The nature of the soil: The particles are very light, hence a relatively small wind velocity only is required to lift and hold them in suspension in the atmosphere.

(c) The practice of Summer fallowing: This greatly aggravates the position.

(d) The disappearance of the protective belt of scrub from side-widths of railway land.

(e) Drought or succession of dry years rapidly increases the area finally denuded of protective vegetation. In wet seasons, except in the worst stretches, cropping or grass growth holds the sand in check.

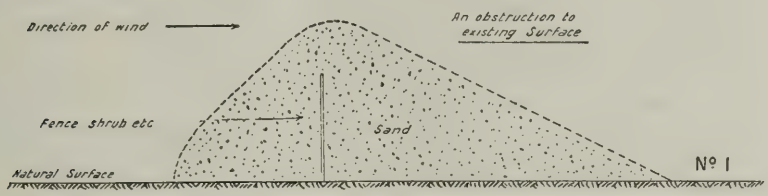
"In dealing with the problem of protection of railway tracks against sand in the Mallee it is essential to remember that the trouble is not due primarily to the pushing or rolling of sand particles before the wind, but to the minute particles carried in suspension in the atmosphere.

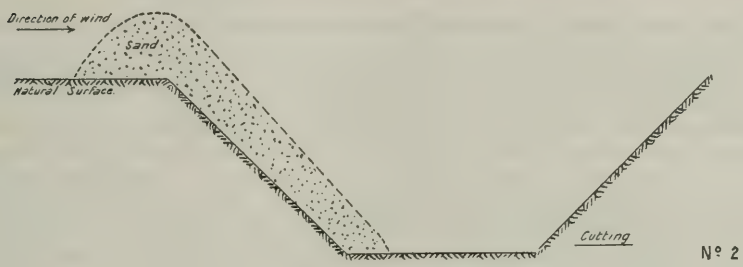
"At a definite velocity (variable according to condition of surface) the sand is lifted and carried along by the air currents until such time as the velocity falls below the rate necessary to overcome the pull of gravity. The amount of sand carried in suspension per unit also depends on the strength of the wind.

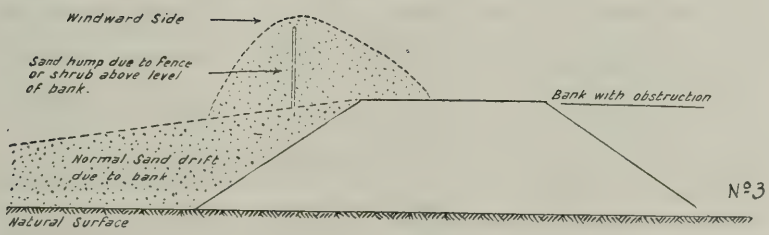
"A fall in velocity occurs when part of the air current strikes an obstacle such as a fence, bush, or dead air pocket such as may be caused by a railway cutting, and sand is deposited, the quantity varying according to size, shape and height of obstacle.

"The sand is deposited on the *windward* side rising higher and higher till the obstacle is topped, then falling over till the normal angle of repose is reached. The height then goes on increasing and with no interference may in time ultimately form a hillock with the crest running parallel to direction of prevailing sand shifting winds.

"The effects at fences, cutting, and banks are shown in sketches below:







"The shallower the cutting the nearer to the track is sand deposited, hence in the earlier stages greater trouble is experienced with shallow than deep cuts.

"Sand piles up against bank on windward side with a long gradual slope against the wind. The leeward side of bank is clear.

Preventive Methods Used

(a) Preservation of Scrub Growing on Railway Reserve

"The side width reservation is generally far too narrow to make a lasting and effective break. As time goes on the scrub is slowly overwhelmed from the fence line and finally the track is reached. The value of this belt is very great and its preservation as long as possible is essential.

In the past, the cutting and burning of the Mallee to protect Telegraph (mainly postal) lines has seriously lessened the life and effectiveness of the break. A notable instance is that of the Mildura line where trouble is being experienced at the points much earlier than it would have been in the ordinary course.

(b) Restoration of Scrub Belt and Planting of Areas Not Previously Covered

"Planting of various types of trees and shrubs (Blue-gums, Tamarisks, Peppers, Bamboos, etc.) has been done in several places without success. Most of the plants were overwhelmed by the sand or died; the few that survived have merely formed a fence over which the sand is building up.

"For practical purposes success in establishing plantations is only possible with large well grown plants put in big areas during a favorable winter so that the trees are well established and sufficiently large before the hot summer arrives.

"Shrubs such as Boolyalla, Wilga, etc., if raised in large quantities may be suitable, but it would be years before any appreciable quantity could be grown. The pepper-tree is also a possibility in view of its drought resisting qualities.

"Re-planting Mallee scrub is not practicable. Seedlings in quantity could probably be raised but their slow growth over a period of many years before they become of sufficient size to withstand the elements renders the proposition useless for dealing with large areas.

(c) Erection of Scrub, Hessian, or Timber Fences

"These fences have been built at different distances from track and at various angles to same or prevailing wind.

"The straight parallel fence is the shortest and it is as effective as any other type. The fence should be away from the track and, subject to certain conditions, as close to boundary fence as possible.

"The function of the fence is to change the direction of the air current with its accompanying disturbance of wind velocities at a more favorable point than the normal one at top of cutting. The sand is deposited and tails out on the ground on top of the cut where it can be scooped clear as required. If no fence or scrub barrier exists the sand would be deposited at edge of cut and tail out down the bank. The shallower the cutting the nearer the top to track and the quicker rails are affected.

"Fences are only of use as protection for cuttings and their value there is in the deposit of the sand at a place where it can be scooped away at comparative leisure as against the constant attention and risk of derailment if allowed to run onto the track.

"For *banks,* fences are not only useless but a menace. Normally the sand piles up against bank on windward side. (see sketch No. 3 below) but should scrub or a fence project above the level of top of bank, conditions similar to those met with at a cutting are set up with attendant troubles.

"The object in dealing with banks should be to have a clear uninterrupted sweep of the wind. At many places removal of the scrub or fence is considered essential.

(d) Planting of Marram Grass, Mesembryanthemum (Pig Face) etc. has been tried successfully to prevent drift (moving) sand, but is useless when dealing with conditions under consideration.

"In "Cassell's Railways of the World" is an interesting article dealing with the investigations of Engineers of the Union Pacific System with the question of the shifting sands of the Columbia River. Whilst their problem is not identical with ours, the results and protective measures adopted are in line with our own.

Removal of Accumulated Sand

The methods adopted by this Department are:—

"(a) Removal of sand by gang to allow passage of train, during or shortly after sand storm. This work is done against time and sand is shovelled to clear rails only.

"(b) Removal by tip trolley on rails or by tip wagon on trolley track alongside. This is done between times to ease position before next storm.

"(c) Scooping out of cuttings (horse drawn scoops). The work is chiefly done during winter months.

"(d) Plant train and special gang. This method is adopted for long cuttings where scoop lead would be too great.

Remarks

"Although there are certain places where sand trouble will be experienced every year and such places are increasing and extending, in the majority of cases the points of attack

depend on the season, cropping and fallowing of the land. Protective action such as erection of fences, clearing the scrub, etc., should only be taken as occasion arises. The clearing of accumulated sand in cuttings or on lee side of fences should be done as often as necessary, but as far as practicable in the early Spring or Autumn.

"Consideration of the class of traffic also is important. The Mildura line with its night passenger trains demands greater precautions and expense than would be justified on other tracks with only an occasional Goods or Mixed train. Under existing conditions a storm will cover the rails within a few minutes.

"In most of the heavy sand country, cuttings are full, or mounds built up on top are ready to tail down after a few more storms. Where fences have been built with the idea of protecting banks or where there is scrub obstruction, the drift there also requires removal.

"Many thousands of cubic yards will require to be shifted and the task is, of course, impossible for the ordinary track force; on some of the lengths the gangs can do little else than keep the track clear for passage of trains and even that involves a large amount of time outside ordinary hours of duty.

"There have been many delays to traffic during present year and several derailments due to sand over rails.

"The prevailing sand shifting winds in the Mallee blow from the Western side of the line hence it is on that side that the main trouble is experienced.

"It is important that Road Foreman and Gangers should have a good knowledge of the underlying principles of defence. Each point requires to be dealt with according to actual conditions. A fence erected too high, or in wrong position, scrub cut incorrectly etc. may ultimately involve the Department in heavy expenditure.

Recommendations

"(1) That where necessary all cuttings in question be cleaned out, and widened to facilitate the use of scoops; the Western side to be given preference.

"(2) That sand on the lee side of fences or mounds on the top of deeper cuttings be removed and top reduced in height where necessary, steps to be taken conjointly to cut out scrub or stumps to facilitate future work.

"(3) That scrub or brush fences and accumulated sand at banks be removed below drift line to top of bank.

"(4) That where directed brush fences be erected to protect the *deeper* cuttings where trouble threatens. Widening *short shallow* cuttings will probably be more economical.

"(5) That instructions be re-issued for the necessity of preservation of the natural scrub in the Mallee and that, except for cutting back to prevent fouling, no interference with the scrub for telegraph line purposes be allowed without instructions from Chief Engineer of Way and Works.

"(6) That where reserves or unalienated land adjoin railway lines, steps be taken to permanently retain a 10 chain belt outside fence line.

"(7) That this Department co-operate with other Departments and interested bodies with view to joint action and exchange of views."

From J. R. W. Davis, Great Northern Railway, with a report by one of his Roadmasters, G. G. Smart:

"Great Northern is troubled in a small way with sand, or sandy loam blowing into its tracks. River sand finding its way onto the track occurs chiefly in the valley on the Columbia, in the State of Washington.

"Sandy loam is troublesome in small areas in the Dakotas and Montana, and to a lesser extent in the State of Minnesota.

From Mr. Smart's report:

"The SP&S has considerable trouble with sand along the Lower Columbia, and they have done considerable oiling of the sand dunes, both on and off the right-of-way. It has been their experience where oil is used it should be of a heavy asphalt base, and should be heated before applying, and the surface of sand dunes given a heavy coating. This is fairly permanent, but has to be gone over occasionally, as if oiled surface is broken, wind will undermine it and start cutting. This is only practical where the area covered with sand is not too extensive.

"They figure that one gallon of oil will coat one square yard in good shape. The cost of applying varies as oil is sprayed on with pressure, a work train equipped with pump, tank cars and facilities for heating being necessary."

And now, having saved the most important until the last, we present a letter, with photographs, from Bernard Blum of the Northern Pacific Railway, in which he describes a type of fence which, instead of stopping and piling up the blowing sand, causes it to blow away, thus avoiding both the risks resulting from drifts and the cost of removing them.

"On some of our branch lines in Central Washington, we traverse sand country, where at times high winds prevail and sand storms are not uncommon. On account of the dryness of the country, vegetation is extremely light and the sand drifts in large quantities.

"Our Maintenance of Way people, through experience, have devised a sand fence which is most effective. I do not fully understand the principle involved, but I have observed it working during heavy winds and know it is very effective. I am attaching several photo prints as we have no standard plan to cover. The posts are cull piles which are driven by a pile driver and the side boards are placed at the top down for a distance of four to six feet, omitting any boards from the ground up for a like space. These fences are placed on the side of the track from which the prevailing winds come and are set about ten to twelve feet from the track. For some reason or other these fences cause a siphoning action and the wind strikes and is deflected down and blows through the open bottom of the fence at an accelerated speed, blowing the sand clear of the track.

Taken Near Casey on Walla Branch About 10½ Miles South of Pasco.

"In some country along our main line we have for some years oiled the slopes of sand cuts, using asphaltum base fuel oil. The oil is sprinkled by work train and the effect of the oil film is lasting so long as the film is not broken. At one place south of Pasco, where there was considerable trouble due to shifting sands, the Northern Pacific in conjunction with the Washington Highway Department sprinkled 180,000 gallons of fuel oil over the sand waste to prevent it blowing across the railroad right-of-way and state highway. The area covered was 72 acres. On the opposite side of this sand waste is located the OWRR&N Ry.

"In previous years the OW had similarly sprinkled the sand lying on the opposite side of their track and the oil film had proven so effective that the Highway Department decided to use the same scheme. The use of oil is expensive and is probably only justified in extreme cases.

"A different type of sand fence, somewhat along the design of portable snow fences, has been used along the SP&S Railway, a subsidiary of the Northern Pacific. The fences are placed in echelon. They serve the purpose well, but require considerable maintenance in raising the fences up as the sand accumulates."

From the information given above, it appears that the most common method of combating drifting sand is by the erection of fences similar to those used to protect against the drifting of snow. One important difference exists, however, between protecting against drifting snow and drifting sand. In the case of snow, it is only necessary to keep the drifts off the road during the winter and the warmer weather of spring removes it from further consideration, but the sand drift once deposited remains to be reckoned with. It is, therefore, evident that the desired remedy in the case of blowing sand is either to prevent its starting to blow or to prevent its drifting at places where it will cause trouble.

Shows Drift to Windward of Track and Fence. Note Guys Fastened to "Deadmen" in Sand to Prevent Fence from Blowing Over.

Two features of the latter plan that have been brought out in the information given above are deserving of further mention. The first is the open bottom sand fence, as described by Mr. Blum. This type of fence acts as a "wind chute", thus directing the force of the wind downward at the critical point, thereby increasing its intensity close to the ground, thus causing it to pick up and carry away the sand with which it comes in contact under such increased pressure. It is very probable that such a fence, built on an angle from the vertical with the top of the fence inclined in the direction from which the wind is blowing might make it even more effective than a fence built vertical.

The other feature is that suggested by others of keeping a railway track half skeletonized where drifting sand is to be contended with. This is in fact Mr. Blum's plan on a smaller scale.

Conclusions

1. Protection against drifting sand, as is the case with snow, should begin with the construction of the road, be it Railway or Highway.

2. Wherever drifting or blowing sand is probable, the roadway should be constructed above the natural ground level where possible and all obstructions which might cause the deposit of sand should be removed and the embankments faced with clay. oiled sand or some other substance which will provide a smooth surface, thus allowing the blowing sand to keep on moving, thereby avoiding drifts.

3. If cuts cannot be avoided, they should be constructed with flat, smooth slopes and the drifting of the sand controlled by the construction of open-bottom wind chute fences as shown on page 400 of Volume 35 of the Proceedings.

4. On existing lines the same remedies should be used where applicable.

5. Wherever sand drifts occur between the rails of a railroad track, the ballast should be cleared out to a half skeletonized condition, to permit the wind to pass under the rails, thus clearing the sand away.

6. Where the source of the blowing sand can be controlled by the planting of vegetation, such treatment may be the most economical method of protection, and should be considered.

7. Where moving sand dunes exist they sometimes may be dissipated by the scattering of gravel or small stones over the face of the windward slope.

8. Where trouble is experienced from sand blowing out of embankments, thus undermining the track, or from its blowing out of the sides of cuts causing slides or other damage the proper remedy is usually the covering of such surfaces with a layer of clay or other stable material.

The Committee recommends that the above conclusions be adopted for inclusion in the Manual and that the rest of the report be accepted as information and the subject closed.

Note—An interesting paper on protection against drifting sand as practiced in Japan was received from Mr. S. Kurokochi, Director, Bureau of Maintenance and Improvement, Japanese Government Railways, after the above report had been completed and ready for publication. This will be considered in a supplemental report next year.

REPORT OF COMMITTEE XXIII—SHOPS AND LOCOMOTIVE TERMINALS

J. M. Metcalf, *Chairman;*
W. H. Barton,
C. E. Beveridge,
H. G. Dalton,
A. G. Dorland,
E. A. Dougherty,
Benjamin Elkind,
C. E. Harris,
A. T. Hawk,
L. C. Hinsch,
W. H. Hobbs,
A. S. Kent,
E. E. Kimball,
L. P. Kimball,
L. H. Laffoley,
H. C. Lorenz,
W. S. McFetridge,
F. E. Morrow,
B. M. Murdock,
J. S. McBride, *Vice-Chairman;*
E. S. Pennebaker,
V. B. W. Poulsen,
E. H. Roth,
W. A. Radspinner,
L. K. Sillcox,
Huntington Smith,
H. W. Williams,

Committee.

To the American Railway Engineering Association:

Your Committee respectfully presents herewith report covering the following subjects:

(4) Turntables (Appendix A.)

(5) Power Plants (Appendix B.)

(6) Wheel Removing Equipment for Engine Houses (Appendix C.)

(8) Car Paint Shops (a) Freight, (b) Passenger (Appendix D.)

Progress is also reported on the following subjects:

(2) Welding Equipment Installations as Applied to Shops and Locomotive Terminals.

(3) General Reclamation Plants, collaborating with Purchases and Stores Division.

(7) Car Wheel Shops.

Action Recommended

1. That the conclusion in report on Subject (4) Turntables in Appendix A be adopted for inclusion in the Manual.

2. That the reports in Appendix B and D be received as progress reports.

3. That the report in Appendix C be accepted as information.

Respectfully submitted,

The Committee on Shops and Locomotive Terminals,
J. M. Metcalf, *Chairman.*

Appendix A

(4) TURNTABLES

L. P. Kimball, Chairman, Sub-Committee; C. E. Beveridge, A. S. Kent, L. H. Laffoley, W. S. McFetridge, B. M. Murdock, E. H. Roth.

The conclusions of the report of this Committee as presented to the 1933 convention were approved for inclusion in the Manual, with the exception of No. 3, which refers to the method of installation for power-operated turntables.

The original recommendation of the Committee indicated a preference for the installation of wiring to turntables in underground conduits. In order to determine the

practice generally employed by railroads in their turntable installations, questionnaire worded as follows was sent to all of the principal railroads.

1. How many turntables do you have operated by electric power?
2. How many of the above turntables have power wires brought in overhead?
3. How many underground?
4. Are your modern installations made with underground or overhead wires?
5. Please advise reason for use of underground or overhead method as preferred.

The replies to this questionnaire are tabulated and totaled below:

Railroad	*Total No. Electrically Operated Turntables*	*Turntables With Power Connections Overhead*	*Turntables With Power Connections Underground*	*Preference*
A. B. & C.	1	1	0	Overhead
Alton	5	5	0	"
A. C. L.	12	12	0	"
A. T. & S. F.	31	4	27	"
B. & O.	52	52	0	"
Bangor & Aroostook	4	4	0	"
B. & L. E.	4	0	4	Underground
Canadian Pacific	2	2	0	Overhead
Central of Ga.	6	4	2	"
Central of N. J.	6	5	1	"
Central of Vermont	3	3	0	"
C. & O.	20	20	0	"
C. B. & Q.	47	47	0	"
C. & E. I.	5	5	0	"
C. & N. W.	36	17	19	"
C. & W. I.	4	2	2	"
C. I. & L.	4	3	1	"
C. C. C. & St. L.	23	22	1	"
Colorado & Southern	8	8	0	"
C. R. I. & P.	35	35	0	"
D. & H.	13	12	1	"
D. L. & W.	18	10	8	Non-committal
D. M. & N.	3	2	1	Overhead
D. & R. G. W.	7	3	4	"
E. J. & E.	6	6	0	"
Erie	25	25	0	"
Grand Trunk W.	7	7	0	Overhead
I. C.	55	16	39	Underground
K. C. Southern	7	7	0	Overhead
L. S. & I.	1	1	0	"
L. V.	19	17	2	"
L. & N.	23	18	5	"
Maine Central	9	7	2	"
M. K. & T.	12	7	5	Underground
Michigan Central	21	3	18	Non-committal
M. & O.	8	8	0	Overhead
Missouri Pacific	5	5	0	"
M. & St. L.	6	6	0	"
N. Y. C. (East)	39	33	6	"
" (West)	35	25	10	"
" (Chgo Term)	15	11	4	"
N. C. & St. L.	3	1	2	Underground
Northern Pacific	35	35	0	Overhead
N. & W.	25	25	0	"
N. Y. N. H. & H.	24	21	3	"

Railroad	*Total No. Electrically Operated Turntables*	*Turntables With Power Connections Overhead*	*Turntables With Power Connections Underground*	*Preference*
P. & L. E.	10	10	0	Underground
Pere Marquette	11	11	0	Overhead
Reading	20	8	12	"
R. F. & P.	3	2	1	Underground
S. A. L.	14	14	0	Overhead
Southern	30	9	21	Underground
St. L. S. F.	14	5	9	Overhead
St. L. S. W.	7	4	3	"
Southern Pacific	25	22	3	"
T. & N. O.	13	13	0	"
Wabash	17	17	0	"
Western Maryland	6	3	3	Underground
Western Pacific	2	2	0	Overhead
(58)	901	682	219	

Of the 58 roads reporting eight (8) expressed a preference for underground connections; with forty-eight (48) reporting a preference for overhead connections and two (2) roads non-committal. The eight roads preferring underground connections have a total of 123 electrically-operated turntables, of which 71 have underground connections actually installed.

Reasons for preference of overhead or underground connections were fairly uniform; those in favor of overhead connections stating that their preference was on account of cheaper installation cost, ease of maintenance and greater accessibility and the avoidance of trouble which might be caused on account of interruption of drainage from turntable pits.

Those preferring underground connections state they consider that such connections will have less maintenance if properly installed; that the question of clearance is eliminated; that there is no deterioration of contactor supports and wiring from smoke and gases; that the underground connection eliminates the possibility of table being put out of service due to damage by fire or storm.

In view of the results of questionnaire the Committee recommends the following text be used for Conclusion No. 3 in place of that recommended last year:

3. Where modern locomotives are to be turned, mechanical power for operating turntables should be provided. Where current is available, electricity is the most reliable means of operating a turntable. The power wires may be led to the table, either overhead or underground. In either type care should be taken to see that installation is made so as to minimize the danger of interruption in case of fire, storm, inadequate drainage or other emergency. Where electric power is not available, a compressed air motor may be used.

Appendix B

(5) POWER PLANTS

E. H. Roth, Chairman, Sub-Committee; B. Elkind, C. E. Harris, L. C. Hinsch, E. E. Kimball, H. C. Lorenz, H. W. Williams.

LOCATION

Power plants at railroad shops and locomotive terminals are usually located in the vicinity of the major terminal buildings, after having given consideration to the plant's economical construction and distribution system. Very often these systems are other than electrical in character, such as steam for firing of locomotives, heating buildings, air pressure, and water supply. A careful analysis of its environment is made, giving consideration to the construction cost, maintenance, operation, and future legal entanglements; having in mind the avoidance of annoyance to the surrounding neighborhood. The adequate and economical delivery of fuel, handling of ashes, abundant water supply, smell of oil, and smoke are considered. Fire risk is given careful investigation as to its surroundings, since a power plant is liable to as great danger from fire in adjacent buildings as within its own walls.

Like commercial power plants, railroad power stations are constructed to supply their products on instantaneous demand, and in maximum amount required for the entire terminal to be supplied.

Space for future extension should be anticipated, in such form that enlargements will not destroy first construction or cause expensive alterations.

SUBJECT ASSIGNMENT

This subject is a new one and as assigned to the Committee on Shops and Locomotive Terminals it has been interpreted to cover the present practices by representative railroads in power plant operation, maintenance and recommended capacity at important locations.

Accordingly, a questionnaire covering the above features was submitted to various railroads, to which thirteen replies were received. The data therefrom has been assembled, which is as follows:

PLANT SIZES

The size of power plants averages 11,530 sq. ft., or about 90 ft. × 128 ft., the largest being 91 ft. × 244 ft. and the smallest 58 ft. × 97 ft.; neither of these two extreme sizes is equipped with electric generator sets. The rated boiler horse power per plant averages 2120, the maximum 6800, minimum 600. The maximum horse power plant reported is used for generating steam for the operation of compressors, water supply pumps (for fire fighting purposes only), and generation of steam for heating purposes. The facilities heated include the roundhouse, locomotive shops, office buildings, store houses, oil tanks, and the numerous shop buildings, located at an important locomotive terminal. The electricity used at this terminal is purchased from a public utility. Steam generated for heating purposes during winter months amounts to about 50 per cent of the total boiler capacity, 25 per cent for the operation of compressors, and the remaining 25 per cent being used as a reserve, or possibility of operating pumps for fire fighting purposes.

The smallest plant generates steam for heating purposes, which includes roundhouse, shop buildings, car shops, oil tanks, office buildings, store houses, and locomotive shops. This plant also is located at an important locomotive terminal, where all water and electric current are purchased from public utilities. The air compressors are electrically operated. About 50 per cent of the steam generated during the winter months is used for heating.

The larger plant uses coal for fuel, while the latter uses commercial fuel oil.

FUEL

The fuels used are coal of various grades, and oil, depending on location. In all cases except two, stokers are used for coal fuel.

GENERATOR SETS

Sixty per cent of the plants are equipped with electrical generator sets, and forty per cent purchase electric power.

AIR COMPRESSORS

All plants are equipped with air compressor sets, operated either electrically or by steam, being on about 50-50 basis. Among those listed in the questionnaires, the largest compressor is of 5000 cubic feet capacity and the smallest 250 cubic feet. The average compressor capacity per power plant is 6020 cubic feet, the smallest 1500 cubic feet, and the largest total capacity per plant 11,000 cubic feet per minute.

WATER SUPPLY PUMPS

Sixty-six per cent of the plants are equipped with water supply pumps, and thirty-four per cent either purchase water from public utilities or have separate pumping plants. In practically all cases drinking water is purchased. The pumps used are for general service and fire.

STEAM HEATING

All of the plants reported on generate steam for heating purposes, supplying various kinds of heaters, such as—Hot Blast, Unit, Direct and Indirect radiation, including hot air distribution. The facilities heated include roundhouses, all classes of terminal shop buildings, oil tanks, coach yards, and office buildings, unit heaters, hot blast, and hot air distribution being generally confined to roundhouses and all shop buildings, while direct and indirect radiation is used in office buildings, diverging somewhat in a few cases, depending considerably upon the local conditions.

FACILITIES SERVED BY AIR COMPRESSORS

Compressed air is used in all shop and locomotive terminal buildings, including car repair yards, coach yards, freight yards, oil tanks and houses, scrap shops, pneumatic tube systems, and furnaces.

LIGHTING SUPPLIED FROM POWER PLANT CURRENT

Current for illumination is purchased in 75 per cent of the cases reporting, the other 25 per cent manufacturing their own current. In the latter cases current is furnished for all buildings and yards or wherever needed in the terminal.

STEAMING LOCOMOTIVES AFTER FIRES ARE DEAD

Only one case reported keeping locomotives under steam by the power plant, averaging ten engines per 24-hour day. Three railroads recommend this practice, one in event conditions and costs justify, six do not, and three are non-committal.

PER CENT BOILER CAPACITY USED IN HEATING

The average boiler capacity used for heating purposes during the winter months for the reporting roads is 52 per cent, for the fall and spring months 27 per cent, and summer months about 1 per cent. The highest usage reported for winter is 80 per cent and the lowest 25 per cent, while for the fall and spring months the highest is 50 per cent and the lowest nothing.

PER CENT BOILER CAPACITY FOR GENERATING ELECTRICITY

Only three railroads reported generating their own electricity for all requirements. These three roads report using an average of 35 per cent of the boiler capacity for winter months, 33 per cent for fall and spring months, and 42 per cent for summer months.

PER CENT BOILER CAPACITY FOR COMPRESSORS

The steam operated compressors average 19.7 per cent of the boiler capacity for the eight railroads reporting on this item, the highest percentage being 50 and the lowest 1½.

USE OF SUPPLY PUMPS

Eight railroads report using power plant water supply pumps for fire fighting purposes, three do not, and two have not reported. Only two railroads report using their own facilities in supplying drinking water, the remainder purchase from public utilities. Eight railroads use their own facilities in supplying wash water, three do not, and two have not stated. Five report using their own facilities for supplying general lavatory use, six do not, and two have not stated. Seven report using their own facilities for watering locomotives, four do not, and two have not reported.

PER CENT OF TOTAL WATER CONSUMPTION

The average percentage of total water consumption used for locomotives for those reporting is 59, for lavatory purposes 17, and for drinking water practically nothing.

RELATIVE COST OF ELECTRIC CURRENT

Seven railroads report purchasing current cheaper than it can be made in their own power plants, three report to the contrary, and three have not determined.

Five recommend allowing space for generators in new power plants, two recommend against, and the remainder suggest making special studies.

RECEIVING AND DISTRIBUTING SUB-STATIONS

Energy is received at the sub-stations where current is purchased at a high voltage and there stepped down to the local demands. In some cases the phases are also changed to meet welding requirements, operation of motors, etc.

TRANSMITTING METHODS

Two general methods are used for transmitting current from power plants or substations, namely: overhead construction or underground conduit depending on distance and local conditions. Within buildings conduit system is in general use. For air and steam both the overhead and underground piping are used, also depending on local conditions.

SUPPORTING STRUCTURES FOR OVERHEAD CONSTRUCTION

The recommendations for supporting structures on overhead construction are fabricated steel towers and expanded metal parts, outside of roundhouse territory, and treated wooden poles within engine territory.

Appendix C

(6) WHEEL-REMOVING EQUIPMENT FOR ENGINE HOUSES

A. T. Hawk, Chairman, Sub-Committee; W. H. Barton, C. E. Beveridge, H. G. Dalton, A. G. Dorland, E. A. Dougherty, L. K. Sillcox, H. W. Williams.

THE EVOLUTION OF DROP PIT EQUIPMENT

In the early days of railroading locomotives were raised by the use of jacks and blocking for the removal of wheels. Because of low roofs, the roundhouse work could not usually be performed in this manner, and the drop pit for the dropping of single pairs of drivers came into general use. At first, this was very crude—simply a pit in which blocking was placed on which stood a jack equipped with a "V" block to engage the center portion of the wheel's axle. The wheels were lowered to a cart resting on the floor of the pit, then were moved sidewise, raised and released.

Two girders equipped with rails on top were used to bridge the drop pit. After the wheels to be changed were jacked high enough to clear these girder rails, the girders were removed from their positions on tops of the side pit walls. First, this change was made by hand. Later, a jib crane equipped with a chain block removed and applied the girders. Later, the girders were hinged at one end, making it possible to swing them into "clear" against the side walls of the drop pit. Even this method resulted in a good deal of manual labor because of their weight.

Later, a track was placed at the bottom of the pit on which ran a flanged wheeled truck that supported a large cylinder, piston equipped. Water or air under pressure served as power. Because of the weight of driving wheels, making a large cylinder necessary, pneumatic power soon had to be replaced by another power, especially as compressed air is exceedingly elastic, causing rapid changes in piston position when loads were imposed on the piston.

The cylinder portion had to be as long as the distance wheels were to be dropped. Dropping a pair of wheels six feet meant a pit 12′ deep. To overcome this, the cylinder of the jack was held to the pit truck at its upper end, the lower end of the cylinder extending a considerable distance below the truck to reduce the depth of the pit, requiring a deep bottom center slot parallel with the pit's side. The slot, because of its narrowness and extreme depth, gave considerable trouble from water and other obstructions. It was difficult to regain tools, locomotive parts and blocks that had fallen into it.

To overcome these objections, the hydraulically-operated telescopic type jack was developed, allowing elimination of the pit slot.

While the jack and pit construction were evolving, the hydraulic equipment to the jack was being improved. At first, large jack cylinders were used to obtain the necessary plunger power provided by the plant water pressure. As weights increased, water pumps hand operated, later power operated, were used, the first ones being air operated. Steam and electricity for this additional power also have played their parts.

Counterbalanced wheels could not be dropped without the wheels turning unexpectedly on the "V" block in attempting to find a balanced position. Frequently, when lowering driving wheels, driving boxes became cramped on one side of the locomotive, causing only one wheel to lower. The mounted wheels slipped sidewise on the "V" block and sometimes fell into the pit. Drop pit jacks for dropping driving wheels, up to and including this stage of jack development, had caused many serious accidents.

As locomotives grew heavier, the running repairs increased. Extended locomotive runs made more wheel work necessary at important terminals and there was a demand for platform tops in connection with drop pit jacks in order to eliminate the hazards of dropping driving wheels by the axle center-support method.

Platform tops resting on a large flat surface at the end of the jack's plunger were a long step towards greater safety. These tops were equipped with rails in alignment with those on roundhouse pits served. Wheels being dropped rested on the platform top served by the jack. The platform tops are of the detachable type and are locked, in rail-level position, to the side walls of the drop pit, allowing the jack to serve other stalls and platform tops. These tops, of course, replaced the hinged girders, equipped with rails, that formerly were used to serve as a bridge over the drop pit.

Platform tops first were of such width across the drop pit as to only drop one pair of driving wheels. Later the width was increased so as to make possible the dropping of two pairs of small drivers or a complete engine or tender truck, and capacities of the jacks were increased to handle these additional loads.

At this period of the jack's evolution, the following objections made necessary a departure in the prevailing design:

1. With a plunger type jack, hydraulically operated, the load rested on a fluid under compression. It was found difficult to obtain positive positioning as the least leakage caused a slight drop of the load, and no check valves could be made absolutely air tight.

2. Many times it was necessary to raise loads greater than seventy-five tons with platform above track level position. Such loading had a tendency to distort and cramp the telescopic sleeves that made up the plunger.

3. The platform top, not attached, but only center-supported on the plunger of the jack, made necessary the center-loading of the weight to be lowered. Careful "spotting" was required and an unbalanced load presented a hazard.

4. The use of water under compression was objectionable, not alone because of its characteristics and the necessity for a clumsy flexible feed line in the pit, but because of the pumping mechanism of the power operated type on the jack truck. Automatic or safety features for this source of power were only obtained with difficulty. Flexible or remote control also could not readily be obtained. In fact, the stage was gradually being prepared for that modern and economical source of power, electricity, the power that was to overcome the objections found in the hydraulically-operated drop pit jack.

Drop Tables

The four-screw electrically-operated drop pit table finally made its appearance. It overcame the objections found in hydraulically-operated drop pit jacks. It was self-locking and could be safely maintained in any position. Its capacity was such that it could handle many operations requiring the platform top above track level position, such as when changing tires or making repairs on spring rigging. Because of a lifting screw at each corner of its top, it could readily handle unbalanced loads, without danger or undue stresses on the table. By using electricity as a source of power, it was possible to safeguard operations through limit and control switches. Furthermore, remote control, through a pendant switch, made it unnecessary for the operator to enter the pit during raising and lowering operations.

The four-screw electrically-operated drop pit table, originally approximately 8 feet in width, also has further developed. The width was reduced in some cases for trailer wheels and single pairs of engine truck wheels. In most instances the width was increased to the extent that two pairs of driving wheels or complete engine and tender trucks could be dropped. A platform top between rails became regular equipment and today a table of the four-screw type can be obtained to meet special requirements, such as varied capacity, power racking, two hoisting speeds, and platform over nineteen feet in width for the dropping of complete four-wheel trailer truck, booster equipped. The modern four-screw electric drop pit table has taken on additional improvements which add to its value in rendering service, such as nested tops and swing gates. The last mentioned have so many advantages that they will be touched on briefly.

In order that complete six-wheel tender trucks or two or four-wheel trailer trucks with boosters can be dropped complete on a platform top approximately ten feet six inches wide, single or double shoulder pits are placed beside the main drop pit. These shoulder pits are about forty inches deep and of a width to suit the needs. These pits are equipped with swing gates pivoted to their side walls, self-supported at their outer ends, and equipped with rails on their tops. When swung to "out" position and locked, they serve as bridges over which the locomotive is run.

After the engine has been moved over the shoulder pits and spotted on the platform top, the gates are swung inward, butterfly fashion, against the side walls of the shoulder pit. The platform top, with its load, is lowered to clear the locomotive or tender. Any parts of the load protruding beyond the ends of the platform top have no interference because of the shoulder pits. For regular wheel dropping arrangements, the swing gates are merely retained in "out" position.

Special Points of Advantage

Because of the use of four elevating screws, the load may be safely held at any height of the table top.

Because of capacity and structure, shoes, wedges, and binders may be applied with drivers, all in one operation, eliminating manual labor.

If the driver drop pit is properly located, and spans more than two tracks, it eliminates the need of additional drop pits for trailers and engine truck wheels.

The following "Wheel Removing" work is possible with this table:

1. Change one or two pairs of drivers.
2. Drop one or two pairs of drivers a short distance for box, journal or frame work.
3. Drop a single pair of engine truck wheels at one operation.
4. Drop a single pair of engine trailer wheels.
5. Drop a single pair of tender truck wheels.

6. Drop and change a complete two or four-wheel engine truck.
7. Drop and change a complete two or four-wheel trailer truck.
8. Drop and change a complete six-wheel tender truck.
9. Drop and change complete booster equipped trailer or tender trucks.

(Operations 8 and 9 are made possible through the use of auxiliary shoulder pits and swing gate.)

General Requirements

The depth and size of pit should be governed by the class of power handled. It should be deep enough to handle the largest wheel along the pit clear of all rail cover supports, and should be wide enough to allow side clearance for man to pass around the dropped wheels.

It is imperative to have the pit well protected against men falling into pit when it is in operation, by means of safety gates or chains, and when pit is not in use it must be fully and strongly covered over to prevent accidents. An overhead crane, jib crane, mono rail and hoists, or a portable crane truck, is necessary to remove this pit covering.

The floor around pit must be of strong rigid construction to resist heavy wear due to handling these heavy wheel and other loads. This may be of reinforced concrete, wood block or asphalt on concrete base.

It is essential that lighting be as nearly perfect as possible. This can be accomplished by flood lights or other good overhead lights, and recessed side light in pit walls, together with ample outlets for plugging in extension cord lights.

No special heating necessary other than that provided for the balance of the house.

It is desirable to install, if possible, a service track or tracks to run between the tracks serving the table, these to extend out through end of enginehouse into back shop instead of the regular pit track. This will allow the full use of the drop table on all tracks served and still allow for the removal of wheels and other heavy parts direct into shop. To accomplish this requires, usually, some special roof carrying trusses in order to clear the floor of posts.

It is also advantageous to extend one of the tracks serving table out through end of enginehouse into back shop (if available) so as to facilitate handling of drivers, other wheels and heavy loads. If back shop is of sufficient size, an engine may be moved over this track into this shop.

It is desirable to construct the stalls at the drop table location longer than the balance of the stalls of the house so that more use of the table can be had, and with closed doors in the winter months. This requires careful study as to proper location of table in the stalls to be served.

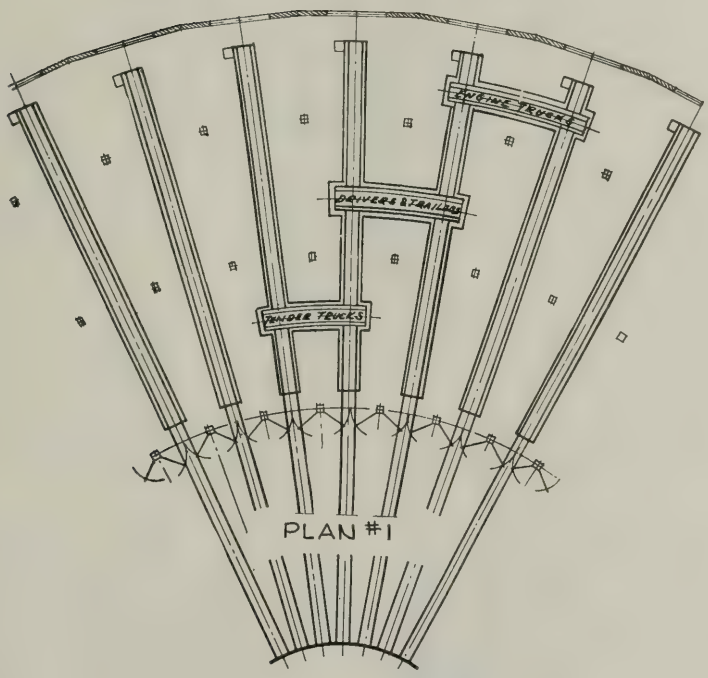
It is very essential to provide adequate drainage to pits to assure a satisfactory working condition in pit and to protect against damage to the electrical part of this equipment.

Selection of Drop Table

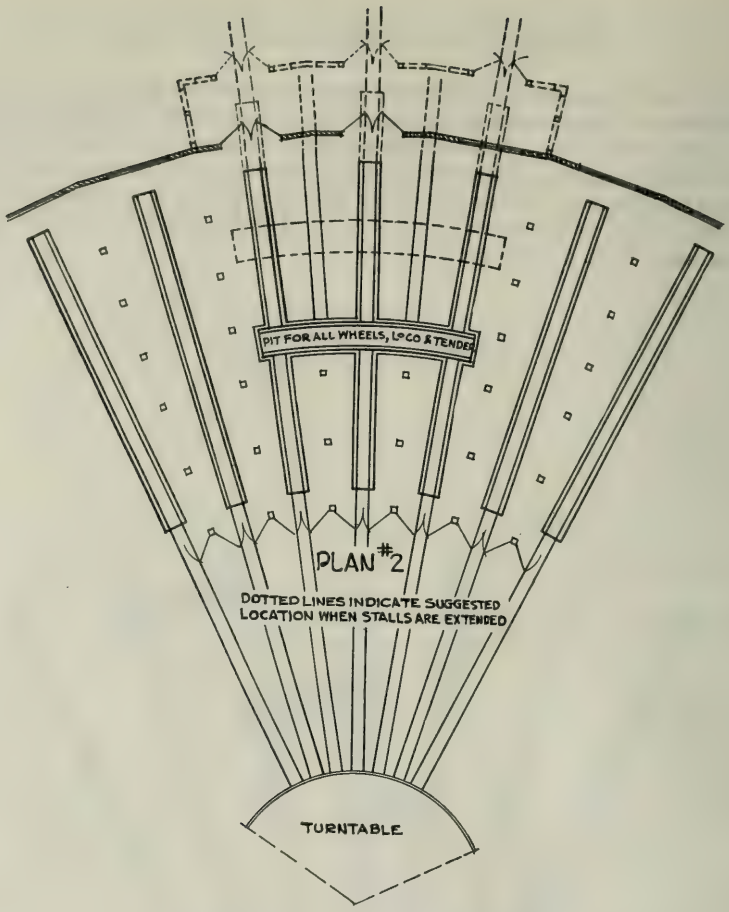
There are many variables, such as amount of repair work performed in engine houses on different railroads, also differences in class of work done in different engine houses on the same railroad; also, some houses have a back shop or main locomotive shop available.

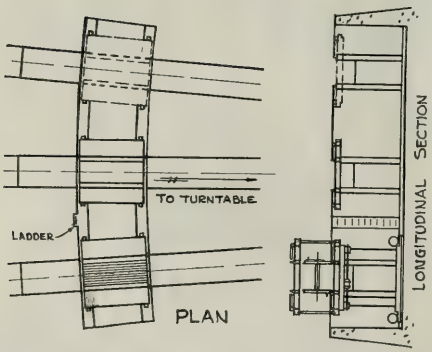
The following assumptions are based on a thirty-stall active enginehouse facility to include a comparatively small but otherwise fully equipped back shop, and responsible for and handling light and heavy running repairs, including general inspection between shopping. (This would include Class 3, 4, and 5 repairs.)

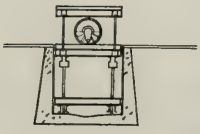
There should be a drop pit available serving two tracks for handling engine trucks; one two-track pit for drivers and trailers, and one two-track pit for tender trucks (see typical sketch, Plan No. 1); or one three-track pit so located and constructed as to take care of all the wheel work (see Sketch No. 2). A plan, cross and longitudinal section are shown on Plan No. 3. These views show the wheels have been removed from the pit at the right and are being released on the stall to the left, raising one top above another, with the center track still in service.



Turntable







PLAN #3

Cross-Section

Appendix D

(8) CAR PAINT SHOPS

A. G. Dorland, Chairman, Sub-Committee; B. Elkind, A. T. Hawk, A. S. Kent, H. C. Lorenz, W. S. McFetridge, F. E. Morrow, V. B. W. Poulsen, W. A. Radspinner.

Questionnaire relative to various features of car paint shops was sent to representative railroads. Replies were received from thirty-two railroads, two of which sent no information; the other thirty replies show a wide variance of recommendations and the following is a summary of these replies.

Car paint shops for freight cars are recommended by twenty-one railroads, and five railroads say they are unnecessary, two say it depends on climatic conditions and two are non-committal. Reasons given for the necessity of a freight car paint shop are many; it avoids delays on account of cold or wet weather; a better and more lasting paint job can be procured when the surface is dry and not too cold; therefore it promotes efficiency and economy.

Car paint shops for passenger cars are recommended by twenty-nine railroads of the thirty replying, the other road is non-committal (having no passenger business.) The reasons for this shop are practically the same as those given for freight car shops with the additional reasons that an even temperature is recommended and that dust and dirt can be kept out, giving a much better finish to the coaches.

Twenty-seven railroads recommend separate shops for painting freight and passenger cars; one railroad says that this is unnecessary, and one does not have enough work for two shops. The class of work is different and the class of paint used is different; when painted by the spray process, paint will get on adjacent cars. Most railroads use entirely different types of work on coaches. All railroads use either varnish or lacquer and many use both; two railroads report using enamel; therefore separate shops are advisable.

The method of preparing cars for painting are varied; for wood freight cars ten railroads have no preparation, sixteen scrape wood cars or use wire brush or both, two burn off the old paint and two wash wood cars; for steel freight cars eighteen sand blast, seven scrape or use wire brush, and two wash cars; for wood passenger cars twenty burn off old paint, five wash and four use brush or scrape; for steel passenger cars eighteen use sand blast, five wash, two use paint remover and five scrape or use wire brush.

While not necessary it is advisable to provide space to do this cleaning outside of the paint shop as the dust and dirt are not conducive to a good paint job; however, to prevent corrosion on steel cars, they should be moved into the shop immediately after cleaning and the first coat of paint applied.

Painting of cars by the spray process is playing an important role in shop operation and shops should be arranged for such work. Where painting is not done by spraying, permanent scaffolding should be provided. These scaffolds should be adjustable and easily operated.

The size of the paint shop naturally depends on the number of days the car must be in the shop, and also the number of cars painted annually. The length of time in the shop depends on the amount of cleaning done in the shop, the number of coats, and the stenciling.

The replies received show the following for freight cars: minimum time in the shop two days and maximum time five days, the average of all roads reporting being three days; for passenger cars the time varies from five days to twenty-one days, the average being twelve and one-fourth days.

From replies received the required capacity of shops in relation to the number of cars in operation was figured on a percentage basis, using a five and one-half day week. For freight car paint shops these replies varied from 0.04 per cent to 0.67 per cent the average being 0.19 per cent. For passenger car paint shops these percentages varied from 0.44 per cent to 4.46 per cent, the average being 1.91 per cent.

The style of shop depends on the amount of the work to be done as well as the layout of car repair shops and the available space for paint shops. Seventeen railroads prefer longitudinal shops for freight cars and six prefer transverse shops. For passenger car paint shops seven prefer longitudinal shops, and fifteen recommend the transverse type. Longitudinal shops should be opened at both ends and transverse shops should have a transfer table unless they are short enough to be served by a ladder track.

The car paint shops should be constructed entirely of fireproof material, with a concrete floor. All shelving should be non-combustible. The shops should be well lighted both naturally and artificially; vapor proof globes should be used; all belting should be eliminated in order that the production of static electricity may be minimized. These shops should be heated and ventilated by the most modern methods; artificial ventilation by fans and blowers if used should provide for circulating all the air in the shop. Especially in lacquer room, openings should be provided at the floor as well as at the ceiling and corners, special attention being given to the specific gravity of the vapors. Fan blades should be rigid and made of non-sparking material, with ample clearance to avoid creating fire by friction, necessary allowance being made for ordinary expansion and loading to prevent contact between moving parts and the duct. Special attention should be paid to the removal of spray paint fumes as fast as they are liberated. This promotes safety and will increase the efficiency of the labor and in addition it will minimize the danger of possible explosion (some lacquers are very combustible.) One manufacturer of paint and varnish recommends that a grate with suction fan be placed beneath each car to carry off the heavier fumes.

Fire hazards are always present in the use and storing of paints and varnishes and these hazards are increased by the use of some lacquers and by the spraying process now in use in most shops.

Six railroads recommend the washing out of the lacquer room monthly, ten railroads weekly, three daily, and one railroad washes out after each lacquer job. For the entire paint shop two railroads wash out annually, five semi-annually, four monthly, four weekly, the others wash out as often as needed. For this reason the concrete floor should have a smooth surface and good drainage; sixteen railroads say this floor should be waterproofed to facilitate cleaning and sixteen recommend that the corners be rounded for the same reason. In old shops with wooden floors the same should be waterproofed.

It is preferable to have the paint stored in a separate building but where this is undesirable, the storage room should be in a room separated from the main shop, this room being cut off from paint shop by standard fire walls and approved fire doors. One railroad recommends underground tanks for paint storage.

Twenty-six railroads recommend separate rooms for the applying of lacquers, said rooms being separated from main shop by standard fire walls and self-closing fire doors.

All electric wiring should be in conduit and it is advisable to have all electric switches for lights, fans or other equipment located in a separate room away from the paint fumes so that there is no danger of an electric spark.

All car paint shops should be provided with approved automatic sprinkler system and a sufficient number of fire extinguishers as well as any other fire protection deemed necessary by local conditions.

The track centers recommended in the replies vary from eighteen feet to twenty-five feet but the average for both freight and passenger shops is twenty feet and the Manual now recommends twenty feet. The distance recommended between the center line of the outer track and the face of the wall varies from six feet to twenty-five feet, the average being twelve feet and nine inches.

The minimum distance recommended between ends of couplers of cars on the same track varies from thirty inches to thirty feet, with the average for freight cars eight feet and for passenger cars nine feet.

The minimum distance between end of coupler and face of end wall; the replies for freight car shops vary from three feet to fifteen feet the average being ten feet five inches; for passenger cars the recommendations vary from three feet to twenty-five feet, the average being eleven feet.

REPORT OF COMMITTEE XIV—YARDS AND TERMINALS

M. J. J. Harrison, *Chairman;*
J. R. W. Ambrose,
Irving Anderson,
C. E. Armstrong,
J. E. Armstrong,
C. J. Astrue,
H. G. Basquin,
H. M. Bassett,
E. J. Beugler,
W. O. Boessneck,
Alfred Bousfield,
N. C. L. Brown,
H. F. Burch,
W. F. Cummings,
R. B. Elsworth,
A. W. Epright,
E. H. Fritch,
E. D. Gordon,
W. H. Giles,
R. J. Hammond,
G. F. Hand,
John V. Hanna,
W. J. Hedley,
H. O. Hem,
W. H. Hobbs,
Noah Johnson,
E. T. Johnston,
E. K. Lawrence,
L. L. Lyford,
E. M. Hastings, *Vice-Chairman;*
C. P. McCausland,
C. H. Mottier,
A. E. Owen,
T. R. Ratcliff,
H. L. Ripley,
H. M. Roeser,
W. B. Rudd,
W. C. Sadler,
C. U. Smith,
E. E. R. Tratman,
H. L. Vandament,
E. P. Vroome,
H. M. Waite,
Committee.

To the American Railway Engineering Association:

Your Committee on Yards and Terminals respectfully presents reports covering the following subjects:

(1) Revision of Manual (Appendix A). It is recommended that revisions relating to (a) freight yards and (b) track scales be approved for publication in the Manual. It is further recommended that the section of the Manual entitled "Specifications for the Manufacture and Installation of Motor Truck, Built-in, Self-contained and Portable Scales for Railway Service" (pages 1034–1050) be withdrawn.

(2) Grain Elevator Storage Yards and Plant Tracks (Appendix B). It is recommended that the report be received as information.

(3) Hump Yards (Appendix C). It is recommended that the report be received as information.

(4) Co-ordination of Facilities at Rail-and-Water Terminals. Progress is reported on the assignment.

(5) Scales Used in Railway Service (Appendix D). It is recommended that the report be received as information. It is further recommended that the specifications contained herein be used during the coming year in lieu of the corresponding Manual material, withdrawal of which is recommended under Item 1, above. It is the present intention of your Committee to submit as Manual material next year the material submitted herewith as Appendix D, revised as may be desirable.

(6) Bibliography (Appendix E). It is recommended that the data be received as information.

(7) Expediting of Freight Car Movements through Yards (Appendix F). It is recommended that the report be received as information.

Respectfully submitted,

The Committee on Yards and Terminals,

M. J. J. Harrison, *Chairman.*

Appendix A

(1) REVISION OF MANUAL

M. J. J. Harrison, Chairman, Sub-Committee; J. E. Armstrong, W. F. Cummings, E. H. Fritch, W. H. Giles, E. M. Hastings, H. L. Ripley, H. M. Roeser, C. U. Smith and E. E. R. Tratman.

PROPOSED REVISION OF SPECIFIED ITEMS OF SECTION OF MANUAL COVERING FREIGHT YARDS

(Present Form)	*(Proposed Form)*
(1) Freight yards are essentially supplementary units and should be so designed and operated in relation to each other and to the lines tributary to them as to give the most economical results for the railway as a whole.	(1) Freight yards are essentially supplementary units and should be so located, so designed and so operated in relation to each other and to the lines tributary to them as to give the most economical results for the railway as a whole.
(5) The type of yard which should be adopted in any given case depends upon the traffic to be handled through it. (a) A single flat yard is adapted for handling traffic where the total number of cars is small and the number of switching cuts per train is also small. (b) A double flat yard is adapted for handling traffic where the total number of cars is large but the number of switching cuts per train is small. (c) A gravity yard or a hump yard is adapted for handling traffic where the total number of cars is large and the number of switching cuts per train is also large—also in special cases where the total number of cars is relatively small but normally received in a short period of time, and the number of switching cuts per train is large and must be made promptly so as to pass the cars through the yard in a limited time.	(5) The type of yard which should be adopted in any given case depends upon the traffic to be handled through it. (a) A single flat yard is adapted for handling traffic where the total number of cars is small and the number of switching cuts per train is also small. (b) A double flat yard is adapted for handling traffic where the total number of cars is large but the number of switching cuts per train is small. (c) A gravity yard or a hump yard is adapted for handling traffic where the total number of cars is large and the number of switching cuts per train is also large—also in special cases where the total number of cars is relatively small but normally received in a short period of time, and the number of switching cuts per train is large. (d) In special cases, due to the location of the yard, the character of traffic, or the arrangement of schedules, it may be necessary to provide a double flat yard or a hump yard, because of limited time for handling.
(23) The number of classification tracks should be such that there will be at least one available for each classification to be made in the yard.	(23) The number of classification tracks should be such that there will be at least one available for each important classification.
(25) In a hump yard where cars of single classifications accumulate rapidly enough to permit of forwarding them in whole trains, the classification tracks may be used as departure tracks with their lengths determined accordingly.	(25) Where cars of single classifications accumulate rapidly enough to permit of forwarding them in whole trains, the classification tracks may be used as departure tracks with their lengths determined accordingly.
(28) The location of the sorting yard should be such that mixed cuts may be	(28) The location of the sorting yard should be such that mixed cuts may be

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moved from the classification yard, sorted, and moved directly to the departure yard without interfering with the operation of the main hump.

(50) Scale tracks should be so located that before cars are classified they may be weighed with a minimum of movement and delay, and where the number of cars to be weighed may exceed 30 in one hour, should be located on gradients such as to permit weighing of cars in motion; a track parallel to the scale track should be provided for non-weigh traffic.

(Proposed Form)

moved from the classification yard, sorted, and moved directly to the departure yard or departure tracks without interfering with the operation of the main hump.

(50) Scale tracks should be so located that weigh cars can be weighed with a minimum delay to yard operation. Where the number of cars to be weighed may exceed 30 in one hour, the scale tracks should be located on gradients such as to permit weighing of cars in motion. A track parallel to the scale track should be provided for non-weigh traffic.

PROPOSED REVISION OF RULES FOR THE LOCATION, MAINTENANCE, OPERATION AND TESTING OF RAILWAY TRACK SCALES

Section I—LOCATION

1.—**General Conditions.**—The proper location of track scales depends principally on the following conditions:

(a) **The volume of traffic to be weighed in comparison with that switched over the scales and not to be weighed.**—The presence of the scale in a much used track is a source of increased cost of maintenance and difficulty in inspecting and testing as well as dangerous to trainmen. In general, in yards not operated by gravity, the scale should not be located in a main drilling lead unless the number of cars to be weighed exceeds 60 per cent of the total number of cars handled or unless the total number of movements over the main drilling lead is comparatively small.

(b) **Whether the scale is to be equipped with dead rail or relieving gear.**—Dead rails should be provided for four-section scales.

(c) **Whether a runaround track will be installed for switching with a separate track for weighing.** Where spot weighing is done, the runaround track is desirable. If cars are to be weighed as classified, the weighing track need be only long enough to clear the dead rail switches. If cars are to be weighed in solid cuts, the weighing track should be long enough to hold a cut of cars to be weighed, both before and after being weighed, in order not to block operation of other tracks while weighing is being done. The weighing track may be located alongside of the drilling track, alongside of the ladder or on an outer yard track.

(d) **Whether cars are to be weighed spotted or in motion.**—If cars are to be weighed in motion the scale must

Section I—LOCATION

1.—**General Conditions.**—The proper location of track scales depends principally on the following conditions:

(a) **The volume of traffic to be weighed in comparison with that switched over the scale and not to be weighed.**—The presence of the scale in a much used track is a source of increased maintenance cost and difficulty in inspecting and testing as well as dangerous to trainmen. Except in special cases, the scale should not be located in a drill track unless the number of cars to be weighed exceeds 60 per cent of the total number of cars handled or unless the total number of movements over the drill track is comparatively small.

(b) **Whether the scale is to be equipped with a dead rail.**—Dead rails should be provided for all scales not designed to support the heaviest locomotives likely to run over the scale rails.

(c) **Whether cars will be switched to a separate track for weighing.**—Where spot weighing is done, a runaround track is desirable. If cars are to be weighed as classified, the scale track need be long enough only to clear the dead rail switches. When a scale track is also a body track, it should be twice as long as the longest cut of cars to be weighed, in order not to block operation of other tracks while weighing is being done. The scale track may be located alongside the drill track, alongside the ladder track, or may be an outer body track.

(d) **Whether cars are to be weighed spotted or in motion.**—If cars are to be weighed in motion the scale must

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be on a gradient in the drilling track at the head of the classification yard.

(e) **The cost of extra switching when the scale is not located on the lead to the classification tracks.**—Ordinarily the cost of the extra switching may be ignored when the integrity of the weights would be affected.

(f) **The cost of maintenance when the scale is located on the lead to the classification tracks and only a small proportion of the cars are to be weighed.**

(g) **The necessity for quick dispatch of cars that are weighed.**

2.—**Position of Live and Dead Rails.**—Live rails should be on the offset line and the dead rails straight unless a large portion of the cars are to be weighed. For motion weighing the offset should be divided, unless the resistance is equalized by means of a spring switch.

3.—**Gradients for Motion Weighing.**—Note.—Attention is called to the following provision of the "National Code of Rules Governing the Weighing and Re-Weighing of Carload Freight"—A.R.A. Circular 1433, May 29, 1914, approved by the I.C.C., June 9, 1914.

"Rule 3–c—Cars may be weighed in motion only when uncoupled and free at both ends and alone upon scales properly designed for weighing in motion and in charge of a competent weighmaster."

(a) **Gradients above the Scale.**—The distance and gradients from the apex of the hump to the higher end of the scale should be so related to the length of the scale and the gradient of the scale rails that a minimum weighing time per car of four seconds will be secured for free running cars.

(b) **Gradients across the Scale.**—The gradient of the scale rails should not exceed one per cent, and the gradient of the track for at least ten feet in each direction from the scale should be the same as that of the scale rails.

(c) **Gradients below the Scale.**—The gradients of the track and the lengths of such gradients below the scale should be such that cars will run by gravity as far away from the scale as desired when their speed over the scale does not exceed that necessary to provide a weighing period of four seconds. Where local conditions make it advisable for car riders to take cuts of two or more cars into the classification yard, the gradient of the scale rails should

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be on a gradient in the drill track at the head of the classification yard.

(e) **The cost of extra switching when the scale is not located on the lead track.**—Ordinarily the cost of the extra switching may be ignored when the integrity of the weights would be affected.

(f) **The cost of maintenance when the scale is located on the lead track and only a small proportion of the cars are to be weighed.**

(g) **The necessity for quick dispatch of cars that are weighed.**

2.—**Alinement of Live and Dead Rails.**—

(no change in body of item)

(no change)

(no change)

(no change)

(b) **Gradients across the Scale.**—The gradient of the scale rails should not exceed one per cent, and the gradient of the track for at least ten feet in each direction from the scale should be the same as that of the scale rails. (See Section II, Item 12.)

(c) **Gradients below the Scale.**—On the assumption that the speed of cars over the scale will permit a weighing time of four seconds, the track gradients below the scale should conform to the A.R.E.A. recommendations for the class of yard. (See A.R.E.A. Proceedings, Vol. 33, pp. 114 and 115). Where local conditions make it advisable for car riders to take cuts of two or more cars into the classification yard, the gradient of the scale rails should ex-

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extend for at least 100 and preferably 200 feet below the scale to enable weighed cars to be assembled in cuts without excessive impacts and to permit all cars involved to be free of the scale when impacts occur.

4.—**Runoff Gradient for Spot Weighing.**—When a scale is installed not in connection with a hump, it is desirable that it be high enough to permit cars to run away from the scale by gravity after being weighed.

Section II—MAINTENANCE AND OPERATION

1.—**Numbering Scales.**—All track scales should be numbered and referred to by number and location.

2.—**Scale Shop.**—Extensive repairs to scales, such as the renewal or the sharpening of pivots, should be made in a properly appointed shop.

3.—**Cleaning.**—When scales are in service regularly, scale parts, substructure and foundations should be cleaned at least twice a month, and when exposed to the elements, or otherwise so located that they are liable to become clogged with ice or dirt, should be cleaned oftener.

4.—**Rust Preventive for Pivot and Bearing Steels.**—The best rust preventive obtainable should be applied to pivot and bearing steels, but it should be so applied as not to interfere with the proper working of the scale.

5.—**Removal of Ice.**—If ice obstructs the action of the scale, salt should not be used to melt it; artificial heat should be used.

6.—**Standing of Equipment Prohibited.**—Equipment should not be allowed to stand on the scale, except when being weighed.

7.—**Restrictions to Use of Live Rails.**—Engines or similar heavy equipment should not be passed over the live rails, except on authority of the department having supervision over the installation and maintenance of scales. The unnecessary passing of cars over the live rails should be prohibited. Weighed cars which have passed beyond the dead rail switch must not be returned over the live rails. The dead rail switches should be set for the dead rail track except when cars are being weighed.

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tend for at least 100 and preferably 200 feet below the scale to enable weighed cars to be assembled in cuts without excessive impacts and to permit all cars involved to be free of the scale when impacts occur.

(no **change)**

Section II—MAINTENANCE AND OPERATION

(no **change)**

(no **change)**

(no **change)**

(no **change)**

5.—**Removal of Ice.**—Ice obstructing the action of the scale should be removed by heat and not by application of salt or any other chemical.

(no change)

7.—**Restriction to Use of Live Rails.**—Engines or similar heavy equipment should not be passed over the live rails, except on authority of the department having supervision over the installation and maintenance of scales. The unnecessary passing of cars over the live rails should be prohibited. Weighed cars which have passed beyond the dead rail switch must not be returned over the live rails. The dead rail switches should be set for the dead rail track except when cars are being weighed. When pushing off the scale cars which have been stopped for weighing or other purpose, impact must not occur at a speed greater than two miles **per hour.**

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8.—**Cars Restricted to Live Rails or Dead Rails Only.**—Cars on the live rails must not be moved by cars or engines on the dead rails or vice versa. Cars must not be moved over the scale with one truck on the live rails and another truck on the dead rails.

9.—**Use of Sand and Injector by Enginemen Prohibited.**—Enginemen must not apply sand or use the injector when on the scale. The slipping of engine drivers on either live or dead rails is injurious to the structure and should be avoided.

10.—**Weigh-beam.**—The weigh-beam should be balanced before the scale is used. When not in use it should be secured by the beam catch and with the poise set at the highest graduation.

11.—**Stopping Cars on Scales.**—Cars should not be stopped on the scale by impact, by the sudden application of brakes or by throwing obstructions under the wheels. When pushing off the scale cars which have been stopped for weighing or otherwise, impact must not occur at a speed greater than two miles per hour. When necessary for any reason to run cars over the live rails, the speed should not exceed four miles per hour.

12.—**Automatic Weighing and Recording.**—Where automatic weighing and recording devices are used it is absolutely necessary that both the scale and the automatic devices be in first-class condition, with properly maintained approach track, and cars must be run at a slow rate of speed with particular attention to steadiness of motion which is essential to obtaining best results.

13.—**Locking Scale Houses.**—Scale house and beam boxes must be kept locked when not being used.

14.—**Inspection by Weighmaster.**—The weighmaster should familiarize himself with the construction of the scale and make inspections at such intervals as are necessary to determine whether or not the scale is in proper working condition. The weighmaster and anyone appointed to inspect and clean the scale should be properly instructed, and it is desirable that they be present with the scale inspector when the scale is tested.

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(no change)

9.—**Use of Sand and Injector.**—The injector must not be used when an engine is over the scale. The slipping of engine drivers on the scale or dead rails is injurious to the structure, but only a sufficient amount of sand to provide the necessary traction should be applied.

10.—**Weigh-beam.**—The weigh-beam should be balanced before the scale is used. When not in use it should be secured by the beam lock and with the poise set at the maximal graduation.

11.—**Stopping Cars on Scales.**—Cars should not be suddenly stopped on the scale by impact or chocking.

12.—**Automatic Weighing and Recording.**—Where automatic weighing and recording devices are used, the scale rails should be smooth, straight, and without joints throughout their entire length. Surface and alinement must be preserved between the ends of the approach and scale rails. The gap between the approach and scale rails should not exceed ¼ in., and should be protected against change by the use of expansion joints in the approach track or other suitable means. The approaches should be maintained smooth so that cars will not reach the scale rails surging on the springs or swaying sidewise. Smooth rolling is essential to the best results. (See Section I, Item 3).

(no change)

(no change)

(Present Form)	*(Proposed Form)*
15.—**Painting.**—The scale mechanism and structural steel should be painted often enough to prevent corrosion.	(no change)
Section III—TESTING	Section III—TESTING
1.—**Tests with Single Test Cars.**—Track scales in regular car weighing service should be tested at least every three months with a test car weighing not less than 30,000 lb.	1.—**Test Frequency.**—Track scales in regular car weighing service should be tested at least every three months. The frequency with which tests should be made depends upon the amount of weighing performed, the character and amount of maintenance attention given the scale, and the consistency or lack of it in results of successive tests.
2.—**Graduated Tests.**—Scales when installed and periodically thereafter should be given a graduated test with two or more test loads up to the weight of the heaviest cars normally weighed. The frequency with which such graduated tests should be made depends on the design, capacity and method of installation of the scale used, the wear of scale pivots, and the amount of weighing performed.	(omit)
3.—**Weekly Tests.**—A test should be made each week by weighing a heavily loaded freight car with as short a wheel base as is obtainable on each end and center of scale. When the scale is equipped with an automatic weighing attachment the car should, in addition to the above, be weighed spotted on the trip end of the scale and in motion with the automatic attachment connected. A report of these tests should be sent to the officer in charge of scales and weighing.	2.—**Weekly Tests.**— (no change in body of item)
4.—**Daily Tests.**—In addition to the above, a daily test should also be made on each scale equipped with an automatic attachment, by weighing a car spotted on the trip end of the scale with the beam, also in motion with the automatic attachment connected. A book record of this and other tests should be kept by the weighmaster.	3.—**Daily Tests.**— (no change in body of item)
5.—**Adjustment.**—Track scales should be kept in the closest possible adjustment, and a scale should be considered inaccurate when it cannot be adjusted, and such adjustment maintained to within two lb. to 1000 lb., in excess or deficiency, when distributed test is made with two or more test loads. When only concentrated sectional tests are made, the maximum error for any position of the test load should not exceed three pounds to each 1000 lb. of test load used.	(omit)

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Section IV—EQUIPMENT FOR TESTING

1.—**Standard of Mass.**—The standards of mass for testing scales should be derived from primary weights, verified by the U. S. Bureau of Standards, to within what is known as their "Class B Tolerance". Such weights can be obtained either direct or through scale manufacturers. The 50-lb. secondary or working cast iron weights, which are transported from place to place and used directly in testing scales, should be rectangular, and of such design as to facilitate stacking, they should be free from pockets, blow holes, etc., which are liable to catch and hold foreign matter. No adjusting cavity or cavities in the bottom of the weights should be permitted.

These weights should be properly painted, surfaces maintained in good condition and be tested and adjusted in comparison with master weights, which have been verified to within "Class C Tolerance". The working weights shall be adjusted to within 25 grains and maintained to within 100 grains of their true values.

NOTE.—The standards for testing scales in the Republic of Mexico must be in accordance with the metric system standards and will be verified by a Federal scale inspector in accordance with the Federal laws.

2.—**Even Arm Balance and Master Scales.**—It is desirable for verifying or sealing test weights and test cars to have, in addition to standards of mass prescribed above:

(a) An accurate even arm balance of 100 lb. capacity in each pan, sensitive when loaded to two grains.

(b) A master scale.

(there is no present Section V)

(For paragraphs of Section V not quoted here, see pages 433, and 434, herein.)

6.—**Scales with Automatic Weight Recording Attachments.**—For scales equipped with automatic weight recording attachments, the test procedure specified herein should be followed with the attachment connected. If the errors found in

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Section IV—EQUIPMENT FOR TESTING

1.—**Standard of Mass.**—The standards of mass for testing scales should be derived from primaries verified by the U.S. Bureau of Standards to within what is known as its class B tolerance. The working standards used in compartment type test weight cars should be rectangular and of such design as to facilitate stacking. They should be free from blow holes, pockets, and the like, which may collect foreign matter. No adjusting cavities in the bottoms of weights should be permitted. The working standards should be properly painted, and adjusted correctly within 25 grains of their nominal values. The surfaces shall be maintained in good condition, and the true value of the weights shall be maintained correctly within 50 grains of their nominal values.

NOTE.—The practice of control just described applies within the boundaries of the United States. In the Dominion of Canada and the Republic of Mexico, the practice shall be amended as required by law or regulation in the respective National jurisdictions or their civic subdivisions.

2.—**Even Arm Balance and Master Scale.**—It is desirable for verifying or sealing test weights and test cars to have, in addition to standards of mass prescribed above.

(a) A balance of 50 lb. capacity in each pan, whose arms are equal within one part in 350,000, and whose sensitiveness is capable of adjustment so that two grains added to either pan when the balance is fully loaded will move the indicator a minimum of one division on the graduated scale.

(b) A master scale.

Section V—DEFINITION OF A STANDARD TEST OF A RAILWAY TRACK SCALE

(Follow material appearing on pages 200–202, Vol. 34, A.R.E.A. Proceedings, with the following exceptions—)

6.—**Scales with Automatic Weight Recording Attachments.**—For scales equipped with automatic weight recording attachments, the test procedure specified herein shall be followed with the attachment disconnected. If the errors in this test

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this test exceed the tolerances applicable, or if routine use is made of the scale from time to time with weigh-beam only, the attachment shall be disconnected, the weigh-beam balanced, and the complete test procedure repeated. If the errors now found exceed the tolerances applicable, corrective adjustments shall be made to the scale proper, whereupon the automatic attachment shall be reconnected and the complete test procedure repeated. If the errors now found exceed the tolerances applicable, corrective adjustments shall be made to the automatic attachment. In no case shall any adjustment be made to the lever system of a track scale to correct for inaccuracy shown by the test to be contributed by the automatic attachment, or vice versa. The scale and automatic attachment must be individually correctly adjusted.

8.—Tolerances.—Every track scale should be kept in the closest possible adjustment, and the weighing performance should be considered unsatisfactory when the scale is not maintained within the appropriate tolerance as herein set forth.

The formally adopted tolerances to be allowed in excess or deficiency on all track scales except grain-weighing track scales are as follows—

(1) Manufacturers' Tolerance. — The manufacturers' tolerance to be allowed on the first field test, after installation corrections, of all new railway track scales shall not exceed 1/20 of 1 per cent, or 50 lb. per 100,000 lb., for any position of the test car load on the scale. The minimum test car load to be applied shall be 30,000 lb.

The SR shall not exceed 50 lb.

(2) Maintenance Tolerance.—The maintenance tolerance on track scales in commercial weighing service shall be—

(a) 2/10 of 1 per cent, or 2 lb. per 1000 lb. of test load, when one test car of seven-foot wheelbase or less is used, the tolerance to be applied to the largest mean of two errors found for different positions of the test car not closer than similar positions on adjacent spans. In no case shall the error at any position exceed 3/10 of 1 per cent, or 3 lb. per 1000 lb. of test load.

(b) 2/10 of 1 per cent, or 2 lb. per 1000 lb. of test load, when two standard test cars are applied on the scale at the same time and at positions not closer together than similar points on adjacent spans.

(c) 2/10 of 1 per cent, or 2 lb. per 1000 lb. of test load, when the wheelbase of the test car exceeds seven feet.

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exceed the tolerance applicable, or if routine use is made of the scale from time to time with the weighbeam only, the attachment shall be disconnected, the weigh beam balanced, and the complete test procedure repeated. If the errors now found exceed the tolerances applicable, corrective adjustments shall be made to the scale proper, whereupon the automatic attachment shall be reconnected and the complete test procedure repeated. If the errors now found exceed the tolerances applicable, corrective adjustments shall be made to the automatic attachment. In no case shall any adjustment be made to the automatic attachment to correct for inaccuracy shown by the test to be contributed by the lever system, or vice versa. The scale and automatic attachment must be individually correctly adjusted.

8.—Tolerances.—Every track scale should be kept in the closest possible adjustment, and the weighing performance shall be considered unsatisfactory when the scale is not maintained within the appropriate tolerance as herein set forth.

The formally adopted tolerances in excess or deficiency on all railway track scales are as follows—

(1) Manufacturers' Tolerance. —

(no change)

(no change)

(no change)

(no change)

(no change)

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(d) 2/10 of 1 per cent, or 2 lb. per 1000 lb. of test load, on two-section scales.

The SR shall not exceed 100 lb.

(2-a) **Maintenance Tolerances on Track Scales Equipped with Automatic Indicating or Weight Recording Devices.**—When a track scale is equipped with an automatic indicating or weight recording attachment, and test is made with such attachment properly connected to the scale mechanism, the tolerances then to be allowed on the indications of the attachment shall be those specified herein for application when no attachment is used. Provided, however, That the minimum tolerance to be applied in such cases shall be the value of one of the minimum graduations. And provided further, that when the mechanism of the automatic attachment is displaced from its position of equilibrium, with a given load spotted on the scale rails, and then permitted to resume its position of equilibrium, the amount by which it fails to return to such position of equilibrium shall in no case exceed the value of one of the minimum graduations.

Tolerance of Grain-Weighing Track Scales.—The "Grain Scale Specifications" published as an appendix to "Rules for the Handling of Bulk Grain in Interstate Commerce and the Filing, Investigation and Disposition of Claims for Loss and Damage incident thereto", issued pursuant to recommendation of the Interstate Commerce Commission, prescribe the following tolerance for grain-weighing track scales—

"Railroad track scales used for weighing grain shall be maintained so that when a test load, consisting of a one-truck short wheelbase test car, standardized on a master scale, is used, the largest algebraic mean of any two errors found for different positions of the test truck shall not exceed one-tenth of 1 per cent, or one pound per thousand pounds of test load applied; provided, however, that no two errors shall be selected corresponding to positions of the test truck equal to or closer together than the distance between the sections of the scale. Moreover, the scale shall be corrected when it is found, on test, that the error exceeds one-tenth of 1 per cent of the test load applied for any position of the test load on the scale. The

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(no change)

(no change)

(3) **Maintenance Tolerances on Track Scales in which are Embodied or to which are Attached Automatic Indicating or Recording Devices.**—For the respective types of scales and conditions of test, the tolerances to be applied to railway track scales in which are embodied or to which are attached automatic indicating or recording devices shall be the same as those applied to railway track scales independent of such devices, except as herein provided.

(a) If the weight is indicated on a dial or reading face, or by means of a printed impression showing the position of an indicating line with reference to a series of graduations, the tolerance shall not be less than the minimal graduation on the dial, reading face, or printed impression, or one five-hundredth of the capacity of the automatic indicating device, whichever is less.

(b) If the weight indication is a printed record in figures representing the weight of the applied load to the nearest unit or multiple of the unit of weight, the tolerance shall be that applicable to the scale independent of the automatic device, plus 50 per cent of the increment between indications that can be printed by the device.

(4) **Tolerance on Track Scales used for Weighing Grain.**—

(no change in body of item)

(Present Form)

manufacturers tolerances on new scales shall be one-half of the above values.

"The sensibility-reciprocal shall not exceed 50 lb. in any case."

Section VI — SPECIFICATIONS FOR RAILWAY TRACK SCALE TEST WEIGHT CARS

(Follow material appearing on pages 169–172, Vol. 34, A.R.E.A. Proceedings, or pages 58–61, Bulletin No. 356, A.R.E.A., June, 1933.)

Section VII—TEST WEIGHT CARS

1.—For general track scale testing test weight cars should weigh not less than a total of 30,000 lb., nor more than 80,000 lb. For making graduated tests and to simplify computations, cars weighing 80,000 lb. and 40,000 lb., respectively, are suggested. The maximum weight of 80,000 lb. is suggested principally in order to reduce the number of restricted movements due to weight limits on scales, bridges, etc.

2.—Test weight cars should be handled on the rear end of trains, just ahead of the caboose.

3.—Test weight cars should not be kept in trains in yards during switching, but should be so placed that rough handling will be avoided. In no case should these cars be subjected to impact at a speed greater than two miles per hour.

4.—All excess weight, resulting from accumulations of snow or ice, should be removed from test weight cars before they are placed on scales for the purpose of testing or on a master scale for calibration. The use of steam is recommended for this purpose.

5.—Test weight cars should be calibrated on a certified master scale before being started on each general test trip, and not less frequently than once every three months. At the time of calibration the actual weight of the car should be made equal to its nominal weight, which should be a multiple of 10,000 pounds.

6.—Each test weight car should be in the care of but one scale inspector between calibrations, and he should be held personally responsible for the maintenance of the correct weight of each car in his care. To this end, the following rules should be enforced:

(a) No repairs to any test car may be made except in the presence of the scale inspector in charge thereof.

(b) Journals of test weight cars may not be repacked unless directed by the scale inspector in charge thereof.

(Proposed Form)

(no change)

Section VII—RULES FOR MAINTENANCE AND TRANSPORTATION OF TRACK SCALE TEST WEIGHT CARS

(Follow material appearing on pages 198–199, Vol. 34, A.R.E.A. Proceedings.)

Foreword.—The purpose of these rules is to establish uniform practice in the maintenance and transportation of track scale test weight cars, to the end of securing uniformity in the quality of track scale test results. The rules are intended to cover all phases of test weight car operation except those incident to testing technic. They are applicable to all cars intended to be maintained at a definite weight, and which are used as standards of mass in testing track scales in either railway or industrial service. For brevity, such cars will be designated subsequently throughout these rules as "test weight cars".

1.—**Classification.** — The circumstances of use require that test weight cars be classified into two major groups, namely, "road test weight cars" and "terminal test weight cars".

(a) Road test weight cars are those required by the circumstances of use to be handled normally in road-haul movements over a considerable territory, in the course of which interchange rules may become applicable.

(b) Terminal test weight cars are those whose field of use is normally within the switching limits of a given locality.

NOTE.—The distinction between (a) and (b), above, is ordinarily but not necessarily one of ownership. Railway owned test weight cars will be usually within the first class, and industrially owned cars in the second. Attention is directed to the fact that interchange rules do not require air-operated brakes on test weight cars.

(Present Form)

(c) Each test weight car should carry a conspicuous badge plate, visible from either side of the car, and carrying a notice to the following effect:

"Do not oil or repack boxes or make repairs to this car unless directed by scale inspector."

(d) Should any change be made in the weight of a test weight car, it is the duty of the scale inspector to determine the amount of such change and immediately to make suitable correction. If the change in weight cannot be determined satisfactorily, the car should be returned to the master scale for calibration before again being used.

7.—The nominal weight of each test weight car should include the car proper and everything contained therein, excepting only such material as is specifically carried as supercargo. This material, consisting of tools, overclothes, etc., when carried, should be contained in a removable steel box, the outside of which should be stencilled to show that it is not a part of the test load. This box and its contents must be removed from the car when being calibrated and when used for testing track scales.

8.—When a test weight car is returned to the master scale for any reason, the actual weight of the car upon its arrival should be determined and recorded. Any unusual variation between that weight and the nominal weight of the car should be promptly and fully investigated.

9.—After the weight of the car on its arrival at the master scale has been determined, the car should receive any heavy repairs which are needed or may be needed before the next trip to the master scale, and should be thoroughly cleaned. At this time the axle bearings should receive any necessary lubrication and packing; after this has been done the car should be calibrated as outlined in paragraph 5 hereof.

(Proposed Form)

2.—**Weight Control.**—

(a) **General.**—All test weight cars are required to be maintained accurately to their designed or nominal weight values. For this purpose, each car shall be verified and corrected as often as may be required, by comparison with the standards of the United States on a scale designated as a master scale by the National Bureau of Standards. A test weight car shall be considered unsatisfactory as a standard of mass when its actual weight differs from the nominal weight by more than sixteen (16) lb. in excess or deficiency.

NOTE.—The foregoing paragraph is intended for literal application within the United States. Within the Dominion of Canada and the Republic of Mexico, it should govern as to permissible limits of variation unless modified by existing law or Governmental regulation.

(b) **Responsibility for Weight Control.**—The scale inspector in charge of each car shall be responsible for its weight control in the interval between successive verifications. It shall be his duty to supervise all repairs and recommend advisable modifications, in addition to and in anticipation of M.C.B. Rules. He shall personally weigh all parts removed and materials added when minor repairs are made enroute between verifications. He shall either attend personally to lubrication or supervise it. Since lubrication is an important factor in weight control, varying in degree with different cars, he shall, with due regard for the requirements of each case, take necessary measures to maintain an adequate supply of lubricant and to keep the weight of the car within the prescribed limits of variation.

(c) **Frequency of Verification Recommended.**—

(1) The frequency required for verifications of a given test weight car will depend upon circumstances of use. Generally, road cars will require verification more frequently than terminal cars. The normal frequency required for any particular case can be determined only by experience.

(2) Road test weight cars, which cover definite territory periodically, should be verified at the beginning and end of each itinerary. If the interval between the end of one itinerary and the beginning of the next is reasonably short, the verification which would normally precede the next itinerary may be omitted. This recommendation presumes that each itinerary can ordinarily be completed without the weight variations resulting from normal use being in excess of the allowable variations.

(Present Form)

(Proposed Form)

(3) Except in special cases where facilities for local control are exceptionally good, twice yearly should be considered the minimum frequency for verification of terminal test weight cars.

(d) **Verification following Repairs.**—Any test weight car should be verified following major repairs for damage or wear, and following repairs or alterations of any kind which involve weight changes that cannot be confidently controlled by weighing material removed and applied.

(e) **Classification of Repairs.**—Repairs to test weight cars may be classified as either major repairs or minor repairs.

(1) Major repairs are those of such nature and extent that, following their completion, verification of the test car weight is required to establish its suitability for use. They include removal and/or repair and/or replacement of wheels, axles, roller bearing assemblies, journal boxes, draft gear and couplers; replacement of lost or destroyed parts whose weight is unknown or whose replacement is likely to cause a weight variation greater than that allowable; repairs of a general nature subsequent to damage by derailment, collision, or the like; and painting.

(2) Minor repairs may include lubrication, and replacement of bolts, nuts, grab irons, air hose, air hose fittings, knuckles, brake rigging, journal brasses, springs, or other parts which either are of known weight or can be weighed on removal and replaced with parts of known weight.

(3) Record of Repairs.—A historical record describing the nature of all repairs should be maintained. When minor repairs are made and the weight control is maintained by weighing the material removed and applied, the record should itemize parts and weights.

(f) **Semi-elliptical Springs.**—If a test weight car is equipped with semi-elliptical springs, each spring, when installed, should have its weight stamped or otherwise permanently marked on the band. If spare springs are carried, each should be marked with its weight.

(g) **Air Equipment.**—Test weight cars equipped with air-operated brakes should have the equipment inspected, cleaned, repaired if necessary, lubricated and stenciled at the time of verification. In any event, such work must be done at such periods that expiration of the interval allowed as a maximum by M.C.B. Rules for operation without reinspection will not occur while a car is on a testing trip.

(h) **Removing Foreign Material.**—Test weight cars carrying accumulations of

(Present Form)

(Proposed Form)

snow, ice or sleet must not be used. Frozen matter may be removed by placing the car in a heated building or by using steam, but not by the use of salt or chemicals. Oil and dirt on the car wheels should be removed by suitable means. Accumulated moisture in closed compartments must be removed whenever circumstances require.

(NOTE.—All compartments and recesses should be made self-draining.)

(i) **Painting.**—Test weight cars should be kept well painted. The finish should have a gloss that can be restored by applying available forms of vehicle polish. Chipped portions of paint surface should be retouched at times of verification.

(j) **Surplus Lading.**—Articles such as car movers, tools, tool boxes, personal effects, etc., must not be included in the nominal weight of a test weight car. One metal chock per car may be so included.

(k) **Inspection preceding Test.**—Test weight cars must be examined by the inspector in charge immediately before each test, with a view to detecting damaged or missing parts or the unauthorized substitution of parts.

(NOTE.—A common operating difficulty is the making of running repairs, such as replacement of brake shoes, knuckles, air fittings, etc., without notification to the scale inspector who is responsible for weight control. It can be offset only by strict vigilance and discipline.)

(l) **Date of Latest Verification.**—This shall be stenciled on both sides of the car.

3.—**Transportation.**

Yard Handling.—Test weight cars should be protected from rough handling at all times. Those equipped with roller bearings should not be "humped" without warning against runaways to the hump foreman and switching crews. Impacts at greater speeds than two miles an hour should be avoided. When uncoupled from a train or cut of cars in motion, the brakes should be manned and, after motion has stopped, firmly set.

DISPOSITION OF OBSOLETE TRACK SCALES

A track scale which has been removed by reason of inadequacy, obsolescence or inaccuracy, should be disposed of in either of the following ways:

(1) Treat as scrap metal after rendering unfit for further use as a scale or parts thereof.

(2) Retain for use as repair parts of existing scales of the same type and size.

Section VIII—DISPOSITION OF OBSOLETE TRACK SCALES

(no change in body of item)

DEFINITION OF A STANDARD TEST OF A RAILWAY TRACK SCALE

1.—**Test Equipment.**—A Standard Test Car, as the term is used herein, is a Test Weight Car which is constructed, operated and maintained according to the applicable specifications and rules adopted by the American Railway Engineering Association.

2.—**Test Car Positions.**—The sections of a railway track scale are numbered 1, 2, 3, etc., from left to right when standing at the weigh-beam and facing the scale deck. Normal positions of a test car are designated in order from left to right as—1R, 2L, 2, 2R, 3L, 3, 3R, etc., the numbers representing the sections and the letters, when affixed, indicating that the body of the car lies to the left or right of the section with one pair of wheels directly over the section. The following are standard combinations of normal test car positions (taking a four-section scale as an example), any one of which combinations may be used when making a standard track scale test.

(a) 1R, 2, 3, 4L.
(b) 1R, 2L, 3R, 4L.
(c) 1R, 2L, 2R, 3L, 3R, 4L.

When testing a two-section scale, the standard combination of normal test car positions is:

1R, Center, 2L.

3.—**Zero Load Balance.**—Any out-of-balance condition of the scale shall be noted by the scale inspector upon his arrival, and the amount thereof be recorded on the report form. After correcting the out-of-balance condition, if any, and before any adjustment or repairs are made, the scale shall be tested as outlined herein. The zero-load balance shall be checked after each run of each test car across the scale, and any out-of-balance condition thus found shall be corrected, and the amount thereof shown on the test report. This correction shall be made by moving the balance ball or other balancing accessories of the weigh-beam. The scale indications shall be read to the nearest 10 lb., and the several readings shall be so recorded on the report form as clearly to indicate that they represent the weighing condition of the scale "as found" or "as left".

4.—**Sensibility-Reciprocal.**—The sensibility-reciprocal (SR) is the change in load required to turn the weigh-beam from a horizontal position of equilibrium in the center of the trig loop to a position of equilibrium at either limit of its travel. In the case of track scales, the construction of which includes a weigh-beam and multiplying indicator connected thereto, the condition of balance of which is shown by the position of the indicator with reference to the center of a series of graduations, and where the total movement of the indicator exceeds one-half inch, the SR is the change in load required to move the indicator tip one-fourth inch from its normal position of balance to a new position of equilibrium.

5.—**Classification of Tests.**—Standard track scale tests are classified as follows, according to the character of testing equipment used:—

Standard Graduated Test.—A standard graduated test is one made with two standard test cars weighing, respectively, not less than 30,000 lb. and not less than 80,000 lb. The weight of the light car should approximate one-half the weight of the heavy car. The standard test procedure is as follows:

(1) Spot one test car at each of the predetermined test positions, and record both the scale indication and the error for each such position.

(2) Spot the other test car at each of the predetermined test positions, and record both the scale indication and the error for each such position.

(3) Spot both test cars on the scale rails, separated by such distance or distances as will result in a condition of loading approximately equivalent to that produced by a freight car, and record the positions, the scale indication, and the error.

(4) Inspect scale, remove binds, do any practicable repair work, and make any advisable adjustments.

(5) If any defective condition is corrected or any adjustment made, repeat tests Nos. 1, 2 and 3, reversing the positions of the cars in test No. 3 when practicable.

Single-Load Test—Standard Form.—The standard form of single-load test is one made with one standard test car, the weight of which is not less than 80,000 lb. The standard test procedure is as follows:

(1) Spot test car at each of the predetermined test positions, and record both the scale indication and the error for each such position.

(2) Inspect scale, remove binds, do any practicable repair work, and make any advisable adjustments.

(3) If any defective condition is corrected or any adjustment made, repeat test.

Single-Load Test—Secondary Form.—The secondary form of single-load test is one made with a test car, the weight of which is less than 80,000 lb. and/or the length of whose wheelbase exceeds seven feet. The test procedure is the same as that for the standard form of single-load test, but the test report must clearly indicate the weight of the test car and the length of its wheelbase.

6.—**Scales with Automatic Weight Recording Attachments.**—(See page 426 herein).

7.—**Test Record.**—The results of the test shall be recorded during the course thereof on a suitable report form. The following information shall be shown:—

(a) Date of test and signature of inspector.

(b) Full and complete identification of the scale.

(c) Classification of test, as determined hereby.

(d) Identification, nominal weight, and length of wheelbase of each test car used.

(e) Balance condition and SR as found by the inspector upon his arrival.

(f) Results of test before any adjustment or repairs are made, with readings and errors to the nearest 10 lb.

(g) The amount of change in zero-load balance after each run of each test car or cars across the scale.

(h) The value of the SR under zero load and under maximum applied load.

(i) Any defective condition found during inspection of the scale.

(j) Any adjustment made to correct the weighing performance of the scale.

(k) Any action taken at the time of the test to correct defective conditions found to exist in the scale mechanism or structure.

(l) Results of test after making adjustment or correcting any defective condition in the scale mechanism or structure, with readings and errors to the nearest 10 lb.

(m) Recommendations of the inspector, unless these are required to be made separately.

(n) Any additional information required by the testing agency, and any unusual condition affecting the test.

Appendix B

(2) GRAIN ELEVATOR STORAGE YARDS AND PLANT TRACKS

W. H. Giles, Chairman, Sub-Committee; Irving Anderson, J. E. Armstrong, W. O. Boessneck, N. C. L. Brown, M. J. J. Harrison, E. M. Hastings, W. J. Hedley, W. H. Hobbs, Noah Johnson, E. K. Lawrence, L. L. Lyford, C. U. Smith, E. E. R. Tratman and H. M. Waite.

An analysis has been made of the replies to a questionnaire sent to 47 railroads by this Committee, and the result of this analysis is the basis of the Committee's report for this year.

The construction of large grain elevators to be served by a railroad involves special yard design.

Modern grain elevators are equipped for the rapid handling of grain. During the season that the grain is moved from field to storage the railroads are called upon to handle large quantities of the product in a relatively short time.

Cars of grain moving into terminals usually are subject to inspection and reconsignment. The carrier bringing the shipment into the terminal designates certain tracks, called hold tracks, for this purpose. After receipt of advice for disposition, the car is moved from the hold track and classified for further movement. If inspection or reconsignment is not required, the movement to and from the hold tracks is unnecessary.

After reclassification from the hold tracks, loaded cars destined to an elevator on carrier's rails are ready for delivery to the elevator storage yard or plant receiving tracks as the case may be. In some cases where the elevator is located within a short distance

of the general yard, and sufficient trackage is available, the cars are held and moved directly from classification tracks to the elevator receiving tracks. Where the elevator is located some distance from the general yard, as in the case at ports or outlying industrial districts, and the plant cannot be served from an auxiliary yard, separate storage yards are sometimes provided. A part of an auxiliary or overflow yard adjacent to general yard and convenient to elevator is sometimes used for the handling of the elevator business.

GRAIN ELEVATORS—GENERAL TYPES

There are three general types of elevator plants, each located, geographically with respect to the class of traffic handled, viz: (1) The rail-to-rail plant, where grain is received by rail for storage and subsequently reshipped by rail; (2) The rail-to-water plant, where grain is received by rail for storage and later reshipped by boats, and (3) The water-to-rail plant, where the grain is received from boats for storage and reshipped by rail. Specific plants may be combinations of these types.

Large rail-to-rail plants are located in most of the principal cities of the central United States and Canada, where the bulk of the grain produced is stored. During recent years, since the inauguration of traffic on some of the principal rivers of the United States, favorably situated rail-to-rail plants have been equipped with auxiliary marine units for receiving and shipping grain by barge.

The rail-to-water plants, and water-to-rail plants are located at the principal ports along the seaboard, Gulf coast, Great Lakes and navigable rivers. Although the primary purpose of these plants is the transfer of grain from rail to boat, or from boat to rail, usually facilities are provided for the occasional reshipment by the same means as received.

ELEVATOR PLANT TRACKS

The arrangement, number and capacity of plant tracks depends upon the type of plant to be served, the position and extent of elevator receiving and shipping facilities, normal receiving and shipping requirements, and local conditions.

Rail-to-Rail Plants

At rail-to-rail plants, separate receiving and shipping tracks are usually provided; at some plants certain tracks are used for both shipping and receiving.

The number of receiving tracks depends upon the arrangement of unloading pits and/or mechanical car unloaders usually located near the "workhouse". The car capacity of the receiving tracks above and below the unloading facilities is, in general, approximately the same, permitting the continuous movement of cars without congestion after being unloaded. Where double ended receiving tracks are provided, loaded cars are placed above the unloading facilities at one end and empty cars are removed at the other. Where spur tracks are provided the loaded cars are pushed to a point above the unloading facilities. As a rule, the carrier's locomotives are not permitted to pass over the unloading facilities or into receiving shed, and idler cars are required properly to place loaded cars on spur receiving tracks.

After the loaded cars are placed on the receiving tracks the elevator forces move the cars to and from the unloading facilities by means of mechanical car pullers, car spotters, or small plant locomotive. In some cases the empty car is moved by gravity after leaving the unloading facilities. A slight descending gradient in the tracks to and from

the unloading point is indicated where car pullers are used. Sometimes an accelerating gradient is also provided immediately below the unloading point.

The car capacity of the shipping tracks above and below the loading point is, in general, about the same and, as in the case of the receiving tracks, permits the continuous movement of cars without congestion after being loaded. At some plants, the receiving tracks are also used as shipping tracks. The placing and removal of cars on shipping tracks, whether double ended or spur, is substantially the same as on the receiving tracks, except that empty cars are placed for loading and loaded cars are removed. The cars, after being placed above the loading facilities, are moved to and from the loading point by the elevator forces with mechanical car pullers or other means.

Rail-to-Water Plants

At rail-to-water plants, the plant tracks are primarily receiving tracks with one or more of these tracks equipped to accommodate the occasional transfer of shipment. A separate shipping track is provided in some cases.

Elevators with their plant tracks located at a congested port occupy valuable property and the space allotted for the track arrangement is somewhat limited. At one rail-to-water plant the receiving tracks are located in two separate parallel groups with the unloading facilities located near one end of the inbound tracks. After the loaded cars are placed in the first group they are moved to the unloading facilities by means of mechanical car pullers and spotters. After leaving the unloading facilities the empty car moves over an accelerating descending gradient gaining sufficient momentum to ascend a gravity switch-back where the car reverses its direction to move through a spring switch into the second group.

The handling of cars to and from receiving tracks at rail-to-water plants is carried out in a manner similar to that at rail-to-rail plants; the method depending upon the track arrangement.

The gradients in the tracks to and from the unloading facilities where mechanical car pullers are used are similar to those of rail-to-rail plants.

Water-to-Rail Plants

At water-to-rail plants, the plant tracks are primarily shipping tracks but usually an unloading unit is located on one of the tracks for the occasional transfer of grain, from car to car.

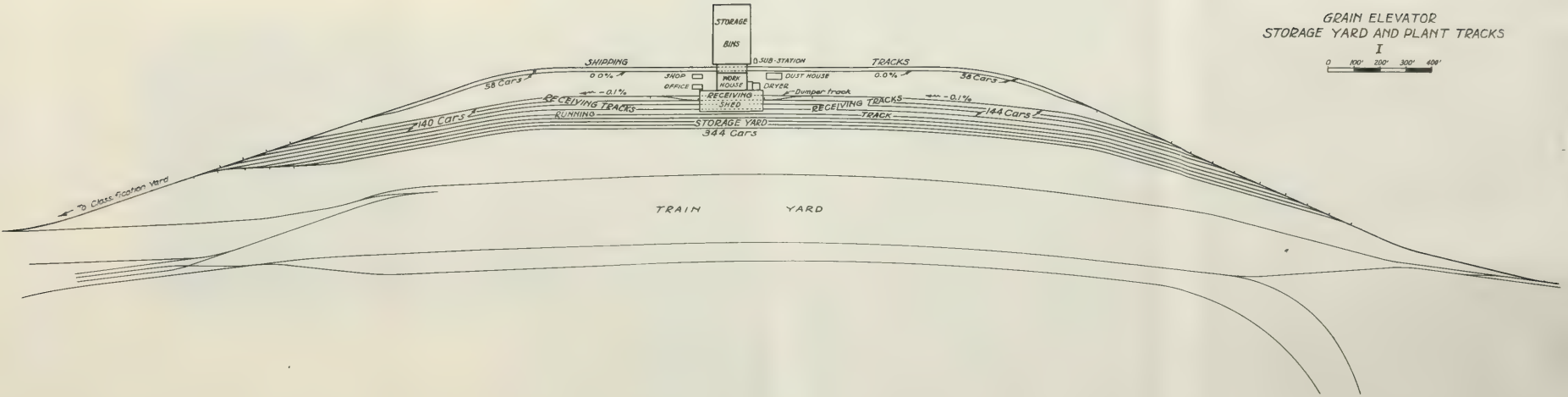
STORAGE YARDS

Storage yards for the purpose of handling grain elevator business are not provided in all cases. It appears that the location of the elevator plant, with respect to the general yard, influences the necessity for this facility. Where the plant is located some distance from the general yard, and no auxiliary yard is available, a storage yard is sometimes provided. This is particularly true where the plant is located in an outlying district of a terminal.

GENERAL

The capacity of the receiving tracks above and below the unloading facilities, as compared with the number of cars unloaded daily, varies according to the location of the plant. It appears that local conditions influence the extent of the plant track facilities, particularly in congested areas. In some cases the capacity of the plant tracks

compares favorably with the average number of cars unloaded or shipped daily in


GRAIN ELEVATOR
STORAGE YARD AND PLANT TRACKS
I
0 100' 200' 300' 400'
STORAGE BINS
SHIPPING
TRACKS
SUB-STATION
0.0%
0.0%
58 Cars
38 Cars
SHOP
OFFICE
WORK HOUSE
DRYER
DUST HOUSE
Dumper track
-0.1%
-0.1%
RECEIVING TRACKS
RECEIVING TRACKS
RECEIVING SHED
RUNNING
TRACK
140 Cars
144 Cars
STORAGE YARD
344 Cars
To Classification Yard
TRAIN YARD

compares favorably with the average number of cars unloaded or shipped daily; in others, a capacity of about one-half the daily business is indicated. At some plants the capacity is small, compared to the business handled, indicating almost continuous use of switching service.

The number and capacity of shipping tracks at rail-to-rail plants is usually less than that of the receiving tracks, due, partly, to the comparative simplicity of the loading device, which can be installed on receiving tracks to augment the capacity of the shipping tracks, and in general the uniformity of shipping requirements.

Where car unloaders are used, two or more receiving tracks usually converge or are connected with crossovers above and below the unloader to provide additional capacity for this device.

A separate track is provided to serve the power house if one is included in the plant layout. At electrically operated plants of modern design the fuel shipments for use in the drier unit are unloaded into storage bins from an adjacent receiving track in some cases.

At some plants, where a gas locomotive is used for handling the cars, a short track extends from one of the receiving tracks to a small building where the locomotive is housed and repaired.

Statement showing characteristics of 47 grain elevators served by railroads in the United States and Canada is included as information.

Fig. 1 is an example of a rail-to-rail plant with separate storage yard.

Fig. 2 is an example of a rail-to-water plant layout.

GRAIN ELEVATOR STORAGE YARDS AND PLANT TRACKS

CHARACTERISTICS OF PLANTS AS REPORTED IN QUESTIONNAIRE

No.	Served by	Location	Local Name	Capacity (bu.)					Legs	
				Workhouse	Bins	Total	Pits	Un-ldrs.	No.	Cap. bu
1	Alton	Kansas City, Mo.	Alton	62,000	631,500	693,500	2	0	2	9,000
2	C.M.St.P.&.P.	Council Bluffs, Ia.	Nye-Jenks	48,000	303,000	351,000	2	0	2	15,000
3	G. N. Ry.	Sioux City, Ia.	Flanley	90,000	268,000	358,000	2	0	2	20,000
4	Erie	Chicago, Ill.	Interstate	75,000	375,000	450,000	3	0	3	18,000
5	Mo. Pac.	Kansas City, Mo.	Eagle	61,400	215,600	277,000	2	0	1	7,200
6	C. B. & Q.	St. Joseph, Mo.	Burlington Public	96,400	828,600	925,000	2	0	3	30,000
7	C. N. Ry.	Annieville, B. C.	Fraser River	110,000	620,000	730,000	4	0	2	30,000
8	Big Four	Indianapolis, Ind.	Ind. Pub. El. Corp.	41,000	959,000	1,000,000	2	0	2	18,000
9	C. R. I. & P.	Council Bluffs, Ia.	Rock Island	250,000	1,000,000	1,250,000	2	0	2	10,000
10	Mo. Pac.	Omaha, Neb.	Elevator "H"	115,700	1,305,300	1,421,000	3	0	4	10,000
11	C. & O.	Newport News, Va.	Elevator "B"	1,000,000	----------	1,000,000	4	0	4	30,000
12	C. B. & Q.	Gibson, Neb.	Neb.-Iowa	110,000	1,000,000	1,110,000	4	0	2	30,000
13	Big Four	Sheldon, Ill.	S. Chicago Elev.	24,000	1,075,000	1,099,000	3	0	1	12,000
14	Alton	Kansas City, Mo.	Kansas Elev.	70,000	1,012,000	1,082,000	4	0	2	12,000
15	Big Four	Indianapolis, Ind.	Cleveland Gr. Co.	250,000	1,500,000	1,750,000	2	0	2	30,000
16	Big Four	Indianapolis, Ind.	Early & Daniel	20,000	1,034,000	1,054,000	2	0	2	24,000
17	I. C.	Omaha, Neb.	----------	140,000	1,012,900	1,152,900	2	1	2	36,000
18	Erie	Jersey City, N. J.	Erie	1,000,000	----------	1,000,000	10	0	10	50,000
19	Wabash	Chicago, Ill.	Rialto	1,080,000	1,545,566	2,625,566	5	0	5	60,000
20	Wabash	Kansas City, Mo.	Wabash	194,820	3,932,880	4,127,700	2	1	4	51,000
21	C.M.St.P.&.P.	Milwaukee, Wis.	Elevator "E"	210,000	2,800,000	3,010,000	4	0	2	18,000
22	C. B. & Q.	Kansas City, Mo.	Murray	420,300	2,000,000	2,420,300	12	0	4	40,000
23	C.M.St.P.&.P.	Kansas City, Mo.	Coburg	250,000	2,650,000	2,900,000	6	0	3	24,000
24	Western Md.	Baltimore, Md.	Port Covington	100,000	3,900,000	4,000,000	8	0	2	30,000
25	Sou. Pac.	Galveston, Tex.	Term'l. Elevator	1,000,000	----------	1,000,000	8	0	2	30,000
26	C. N. Ry.	Saskatoon, Sask.	Gov't Elev.	500,000	5,000,000	5,500,000	9	0	3	36,000
27	N. Y. C.	New York, N. Y.	Elevator "A"	1,500,000	----------	1,500,000	10	0	10	35,000
28	C. & N. W.	Council Bluffs, Ia.	Updike	310,000	2,190,000	2,500,000	12	0	3	48,000
29	C. B. & Q.	St. Louis, Mo.	Burlington "A"	108,000	2,206,500	2,314,500	8	1	11	89,000
30	C. & O.	Chicago, Ill.	Calumet	3,000,000	1,000,000	4,000,000	13	0	13	91,000
31	Reading	Philadelphia, Pa.	Port Richmond	500,000	2,000,000	2,500,000	5	2	3	75,000
32	G. N. Ry.	Superior, Wis.	Elevator "S"	3,100,000	8,380,000	11,480,000	18	0	9	90,000
33	A. T. & S. F.	Argentine, Kas.	Elevator "A"	529,400	10,000,000	10,549,400	2	4	4	100,000
34	B. & O.	Baltimore, Md.	Locust Pt.	800,000	3,000,000	3,800,000	4	4	4	100,000
35	Mo. Pac.	St. Louis, Mo.	Mo. Pac. Elev.	263,100	3,499,400	3,762,500	12	0	3	36,000
36	Mo. Pac.	Kansas City, Mo.	Continental Elev.	237,150	2,263,040	2,500,190	6	1	3	36,000
37	C. & N. W.	Milwaukee, Wis.	Kinnickinnic Elev.	300,000	3,000,000	3,300,000	12	1	3	45,000
38	C. P. Ry.	Ft. William, Ont.	Elevator "D"	300,000	7,200,000	7,500,000	16	0	4	48,000
39	Galv. Whf. Co.	Galveston, Tex.	Elevator "B"	470,366	5,333,680	5,804,046	16	0	4	100,000
40	C. N. Ry.	Churchill, Man.	Gov't. Elev.	500,000	2,000,000	2,500,000	4	4	4	80,000
41	Mo. Pac.	Kansas City, Mo.	Kas.-Mo. Elev.	511,150	5,203,750	5,714,900	9	1	4	50,000
42	C. P. Ry.	W. St. John, N. B.	----------	1,032,000	----------	1,032,000	16	0	8	96,000
43	C. & N. W.	Chicago, Ill.	Terminal	1,709,000	8,291,000	10,000,000	24	0	6	120,000
44	C. N. Ry.	Port Arthur	Pool No. 7	900,000	6,000,000	6,900,000	5	5	5	125,000
45	C. P. Ry.	Pt. McNicoll, Ont.	----------	184,000	6,316,000	6,500,000	1	0	1	2,000
46	C. N. Ry.	Collingwood, Ont.	Collingwood Tml.	100,000	2,000,000	2,100,000	1	0	1	30,000
47	C. N. Ry.	Depot Harbor, Ont.	Depot Harbor Ele.	150,000	1,450,000	1,600,000	----	----	----	--------

GRAIN ELEVATOR STORAGE YARDS AND PLANT TRACKS

CHARACTERISTICS OF PLANTS AS REPORTED IN QUESTIONNAIRE

Receiving							Shipping											No.
Tracks					Cars Unl'ded Dly.		Spouts		Tracks					Crs L'ded Dly.		Storage Tracks		
No.	Cap. (a)	Cap. (b)	Grad. (a)	Grad. (b)	Max.	Ave.	†		No.	Cap (a)	Cap. (b)	Grad. (a)	Grad. (b)	Max.	Ave.	No.	Cap.	
2	15*	12*	0.3%	0.3%	80	50	----	2	1	20	17	0.3%	0.3%	110	90	Ge	n'l. Yd.	1
2	40	40	0.2,0.0	0.2%	70	20	2	----	Sa	me a	s rec	eiving		70	20	No	ne	2
1	20	20	+0.0%	+0.0%	--------	--------	----	3	2	26	26	+0.0%	+0.0%	100	50	Ge	n'l. Yd.	3
1	32	16	0.0%	‡0.0%	60	20	----	8	1	26	15	0.0%	‡0.0%	60	20	N	one	4
2	41	46	0.1%	0.1%	40	15	1	1	2	40	45	0.1%	0.1%	50	50	G	en'l. Yd.	5
1	----	----	--------	--------	--------	--------	----	2	2	----	----	--------	--------	------	------	----	--------	6
2	60	60	0.23%	0.5%	--------	--------	2	----	----	----	----	Rail to	water			Ge	n'l. Yd.	7
2	25	26	0.83%	0.5%	48	24	2	----	Sa	me a	s rec	eiving		48	24	Ge	n'l. Yd.	8
1	9*	9*	0.2%	0.0%	45	35	----	1	1	9*	9*	0.2%	0.2%	------	------	Ge	n'l. Yd.	9
2	26*	13*	0.0%	0.0%	69	30	2	4	4	52	33	0.0%	0.0%	84	50	6	43	10
2	22	56	1%	0.5%	200	175	4	----	Sa	me a	s rec	eiving	------	50	50	10	230	11
2	----	----	--------	--------	--------	--------	----	2	2	----	----	--------	--------	------	------	----	--------	12
3	40	112	0.8%	0.7%	26	22	2	----	2	28	60	0.8%	0.7%	60	50	No	ne	13
2	19*	19*	0.3%	0.3%	110	90	1	2	2	19*	19*	0.3%	0.3%	160	130	Ge	n'l. Yd.	14
2	28	34	0.5%	0.5%	60	30	1	1	2	28	34	0.5%	0.5%	50	50	3	65	15
2	28	28	1%	1%,0.7%	30	30	1	1	3	38	38	1%	1,0.7%	30	30	Ge	n'l. Yd.	16
2	44	50	0.15%	0.75, 0.16%	75	50	2	2	3	62	68	0.15%	0.75,0.16	% 75	50	Ge	n'l. Yd.	17
2	14	----	0.0%	0.0%	360	216	----	----	----	----	----	Railto	water	------	------	Ge	n'l Yd.	18
2	12	----	0.0%	0.0%	120	70	----	5	1	15	5	0.0%	0.0%	50	20	2	36	19
1	25	34	0.2%	3%R.O.	114	52	----	5	2	49	49	0.0%	0.0%	105	------	14	728	20
6	260	26	0.2%	0.2%	120	100	----	3	1	16	20	0.1%	0.2%	336	300	6	260	21
3	75	75	--------	--------	--------	--------	8		Sa	me a	s rec	eiving	--------	------	------	5	280	22
2	40	80	--------	--------	90	10	1	6	3	55	100	--------	--------	120	60	Ge	n'l. Yd.	23
4	56	267	0.5%	1.5%	360	300	3	----	2	28	138	Railto	water	------	------	17	350	24
4	56	52	0.0%	1.5%	240	--------	----	2	3	75	36	0.0%	0.0%	72	------	5	130	25
3	75	75	0.35%	0.5%	216	180	3	6	3	74	74	0.35%	0.5%	432	360	2	138	26
2	10	10	0.0%	0.0%	120	105	----	8	1	6	6	0.0%	0.0%	60	30	13	150	27
4	100	90	0.1%	0.7%	--------	--------	3	----	2	50	45	0.1%	0.7%	------	------	11	300	28
3	----	----	0.0%	2%R.O.	--------	G.L.	----	11	3	----	----	--------	--------	------	------	----	--------	29
6	----	----	0.0%	0.0%	140	100	13	----	Sa	me a	s rec	eiving		110	100	Ge	n'l. Yd.	30
3	127	150	0.0%	1.5,1%	R=384	R=300 C.S.	4	----	1	24	----	Railto	water	------	------	14	475	31
2	18	18	--------	--------	300	--------	5	----	----	----	----	Railto	water	------	------	17	305	32
6	572	589	--------	--------	R=750	174	8	----	Sa	me a	s rec	eiving		151	103	14	605	33
5	100	112	0.0%	1.4%	--------	--------	1	----	1	----	----	Railto	water			----	240	34
4	72	76	0.0%	0.0%	160	100	2	4	2	36	34	0.0%	0.0%	80	40	8	125	35
4	144	140	0.1%	0.0%	139	70 G.L.	4	4	4	120	116	0.0%	0.0%	66	32	4	344	36
4	84	84	0.1%	1-0.5%	240	--------	6	----	2	42	42	0.1%	1,0.5%	------	------	9	150	37
4	116	150	0.1%	0.1%	309	225	14	----	2	50	50	Railto	water	------	------	2	82	38
4	46	35	0.5%	0.5%	--------	--------	4	----	2	----	----	Railto	water	------	------	Ge	n'l. Yd.	39
4	106	95	0.825%	2,0325%	--------	--------	1	----	1	25	21	Railto	water	------	------	Ge	n'l. Yd.	40
5	114	148	0.0%	0.0%	114	80 G.L.	3	8	3	63	63	0.0%	0.0%	117	60	4	133	41
4	66	50	0.0%	0.0%	163	91	----	----	----	----	----	Rail to	water	------	------	Ge	n'l. Yd.	42
4	110	120	0.1%	1.06%	--------	--------	3	3	2	69	76	0.1%	1.06%	------	------	20	1230	43
10	225	225	0.2%	2,0.4%	3	200	6	----	2	25	25	Railto	water	------	------	16	620	44
1	20	40	--------	Water	to rail		----	6	2	40	80	0.2%	0.2%	480	20	4	150	45
1	4	----	--------	Water	to rail	--------	----	2	2	34	60	0.2%	0.45%	130	80	4	125	46
----	----	----	--------	Water	to rail	--------	----	2	1	25	25	0.0%	0.0%	240	180	Ge	n'l. Yd.	47

(a)—Above unloading or loading point.
(b)—Below unloading or loading point.
R—Rated capacity.
G. L.—Small plant locomotives used for spotting cars.
C. S.—Mechanical car spotters used.

*—Capacity unsatisfactory.
†—Located on receiving tracks.
‡—Grandient unsatisfactory.

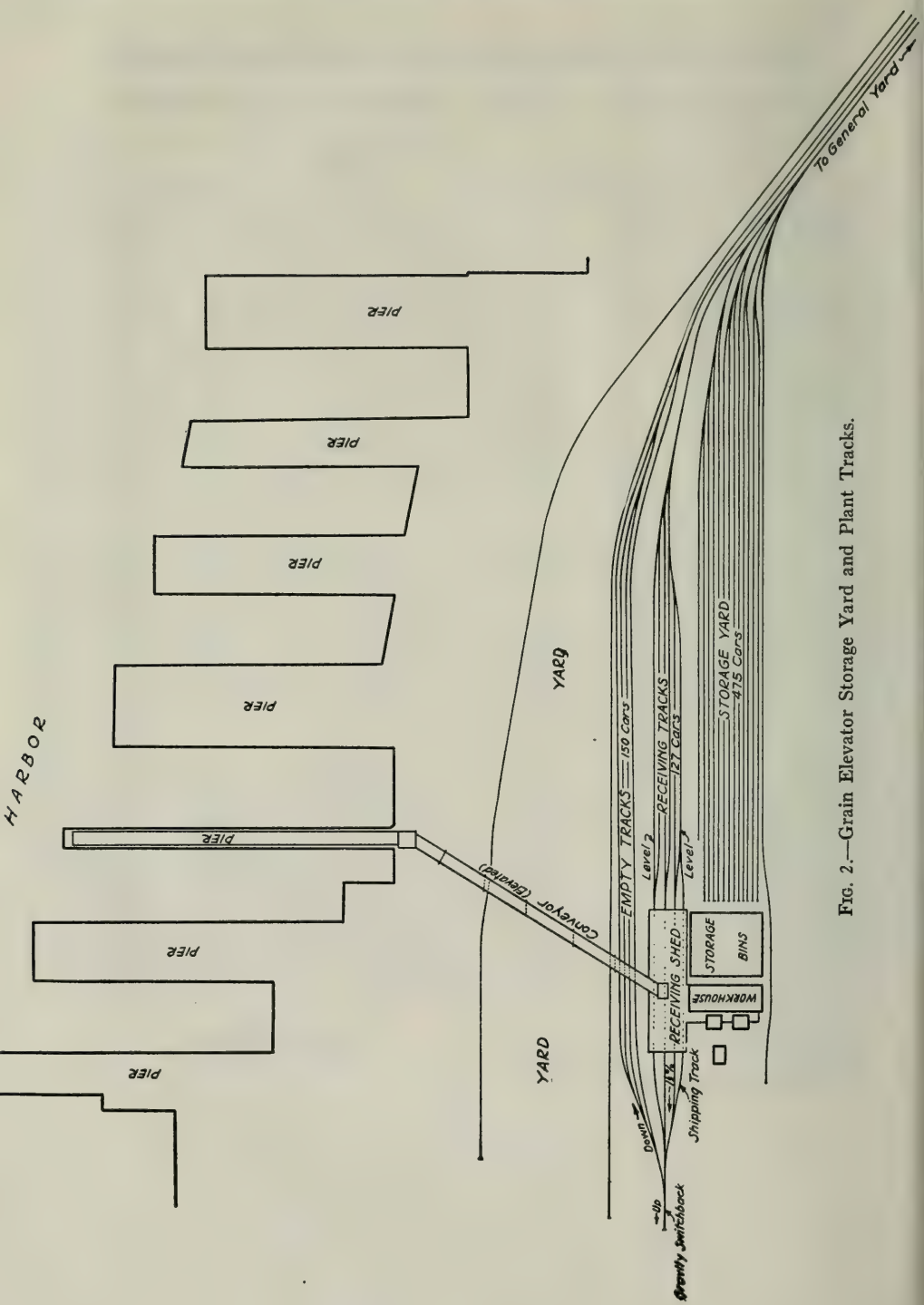


FIG. 2.—Grain Elevator Storage Yard and Plant Tracks.

Appendix C

(3) HUMP YARDS

E. M. Hastings, Chairman, Sub-Committee; J. R. W. Ambrose, N. C. L. Brown, H. F. Burch, W. F. Cummings, R. B. Elsworth, R. J. Hammond, G. F. Hand, J. V. Hanna, M. J. J. Harrison, C. P. McCausland, C. H. Mottier, T. R. Ratcliff, H. L. Ripley, W. B. Rudd, W. C. Sadler, E. P. Vroome and H. M. Waite.

There was submitted for the information of the Association at the March 1933 meeting a report covering what is termed the graphic method to be used in designing gradients in connection with the application of car retarders to hump yard operation. Two graphic methods were described, "A" and "B". Your Committee for this year presents for the information of the Association further discussion of the matter, particularly information concerning application under Graphic Method "B". Reference is made to the sub-committee report to the March 1933 Convention (see page 177, Vol. 34 of the Proceedings). Reference is also made to the Fig. 5 accompanying that report showing typical classification yard of fifty tracks. The following application and discussion is based upon this track layout. The figures accompanying this report are numbered numerically as a continuation of the report of last year.

(I) APPLICATION TO THE DESIGN OF CLASSIFICATION YARD GRADIENTS

Some of the basic principles described in Section I, Graphic Method "B" (see page 183, Vol. 34 Proceedings) are useful in designing gradients when compensation for curvature is desired, since they may be used to portray the approximate car speeds to be expected with various gradients, thereby indicating the locations where compensation should be used. Also they are useful in representing the releasing speeds necessary to secure the proper movement of cars in accordance with their various resistances, thus illustrating some of the problems encountered by an operator and perhaps leading to the most satisfactory design of the gradients.

Fig. 9 and 10 show equivalent gradients which have been drawn to include the curve resistance which may be found in a car running on each of several different tracks which differ either in the amount or location of the curvature and finally show the gradients upon which fairly uniform car speeds may be obtained. The resultant velocity head profile shows also the variation in car speeds which cannot be avoided.

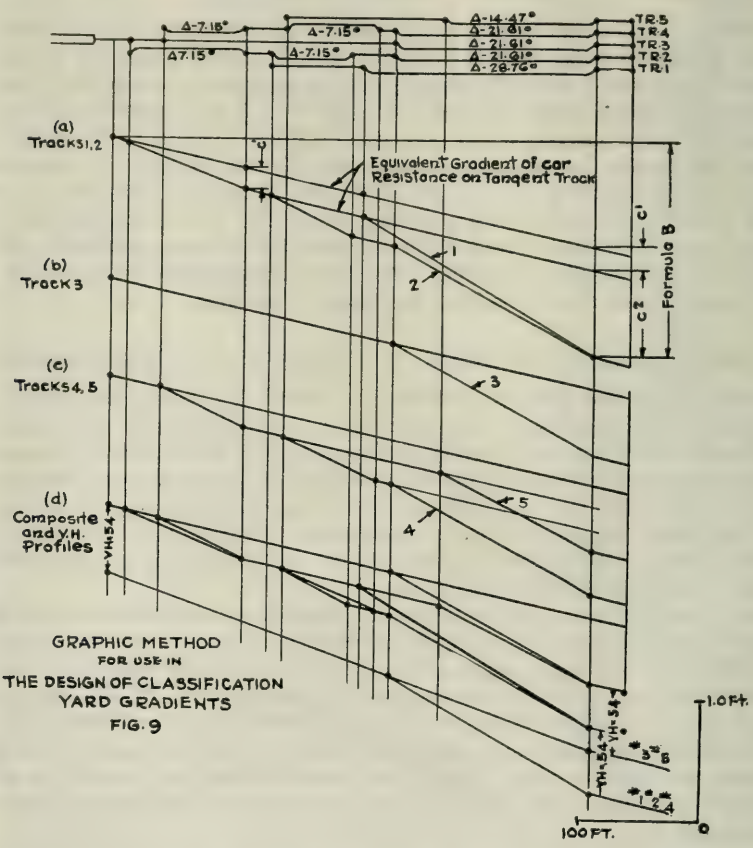
The track arrangements are shown diagrammatically but the lengths of track and curvatures are drawn to scale. Each of the curves including the turnouts are marked to indicate its central angle. In Fig. 9 four groups of various types of profiles are shown as follows:

(a) A line is drawn at a slope which represents a gradient of 0.22 per cent, equivalent to a resistance of 4.4 pounds per ton for a car running on tangent track. The vertical height C_1 represents the drop which, at the rate of 0.025 ft. per degree of central angle, would be required to compensate for a curve having an included angle of 7.15°, and the line drawn underneath the curve represents an equivalent gradient which includes the curve resistance. A similar equivalent gradient is drawn, using a value C_2 for the curve having a central angle of 28.76° and then the lower series of lines represent a gradient equivalent to the resistance of a car running to track 1. It will be found that results, obtained from using Formula B, as found on page 129, Vol. 33, but with (b) omitted will equal the drop represented by the notation "Formula B".

(b) Similar profiles are shown for track 3.

(c) Similar profiles are shown for tracks 4 and 5.

(d) A composite of the profiles of the above tracks is shown together with gradients designed to provide a fairly uniform speed for the car in running from the last retarder to tangent track but at least so that, regardless of the track over which it runs, it will leave the last retarder with a velocity head of 0.54 ft. (4 m.p.h.) and will arrive on tangent track with the same velocity head. Also it will be noted that the gradients are arranged, so that the compensation has, as nearly as possible, a direct relation to the curvature for which it is added.



GRAPHIC METHOD
FOR USE IN
THE DESIGN OF CLASSIFICATION
YARD GRADIENTS
FIG. 9

In Fig. 10, three groups of profiles are shown to illustrate the gradients derived from a similar study of tracks 21 to 25, inclusive, and if this is done for all tracks the gradients will be designed substantially in accordance with method No. 1 as described in this Committee's report found on page 130, Vol. 33 of the Proceedings.

The graphic method may be of assistance in studying the operation obtained with gradients designed in accordance with the seven methods of application set forth in the above mentioned report. Thus far, in this report, the only resistance considered has been 4.4 pounds per ton but it is obvious that there will be other resistances varying from at least 4.4 pounds per ton to 18.0 pounds per ton (see page 131, Vol. 33 of the Proceedings). If all cars are to be run to clearance at speeds which are suitable for coupling with other cars, the operator must adjust the releasing speed of such car in

accordance with its rolling qualities, the resistances peculiar to each track, and the distance through which it must run before coupling. The problems of an operator will depend upon the range of releasing speeds necessary to satisfy all car resistances encountered and his efficiency on his ability to judge such speeds. Therefore, the various methods of designing gradients should be considered from the viewpoint of releasing speeds.

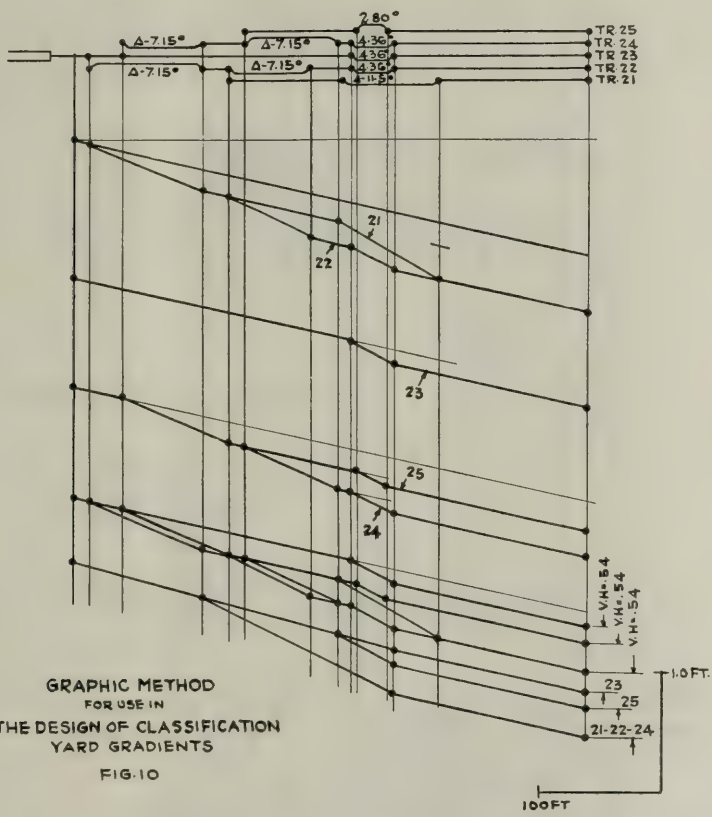
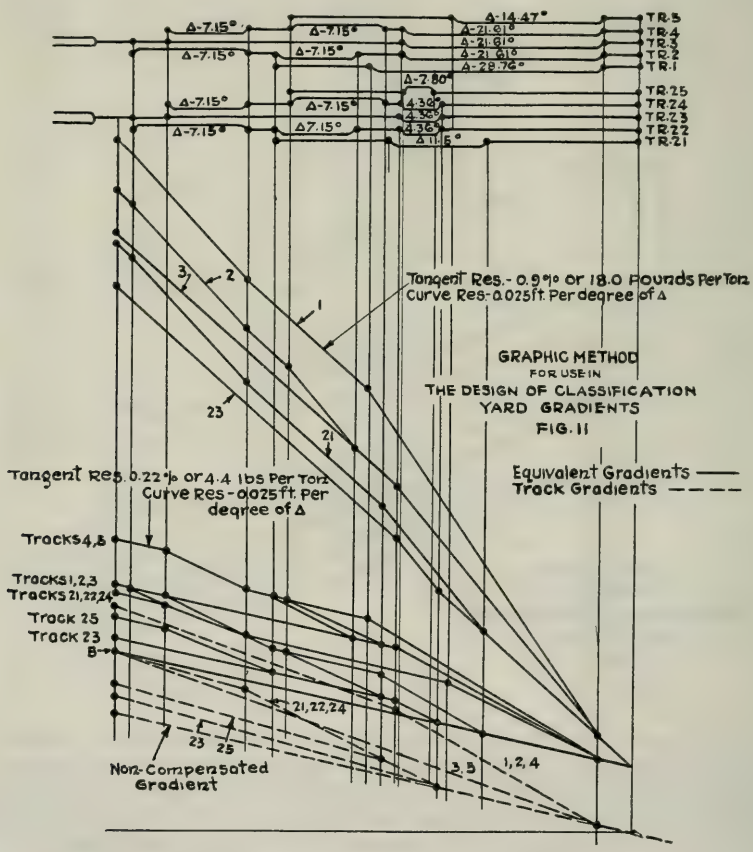


Fig. 11 shows the two groups of tracks together with the equivalent gradients and track gradients developed in Fig. 9 and 10, these having been plotted from an equivalent point in each classification track where all cars are to have the selected practicable speed of 4 miles per hour (0.54 ft. VH). Also there is shown a group of equivalent gradients for a car having 18.0 pounds per ton resistance to represent the hard rolling car. The velocity head values at the last retarder, as measured between the equivalent gradients and their corresponding track gradients, represent the releasing speeds required under various conditions.

Method 1

This method involves grading each track with its proper amount of curve compensation. The velocity heads of the releasing speeds would be approximately as shown, the range being from 0.54 ft. (4 m.p.h.) to 3.39 ft. (10 m.p.h.) for cars having resist-

ances as shown. However, if there should be cars having practically no curve resistance, a condition which has been recorded in testing, an acceleration of the easy rolling car would result, thus requiring a lower releasing speed to secure the proper final speed. It will be noted, further, by comparing the equivalent gradient B, for a car having no curve resistance, with the track gradient for tracks 1, 2 and 4, that a negative releasing speed would be necessary, thus indicating that even if such a car be brought to a stop and then released, the final speed will exceed 4 m.p.h. (.54 VH). This may not be an objectionable condition if the maximum speed of the car throughout its travel on the classification track does not exceed 6 m.p.h. However, for comparison, the range of releasing speeds should include 0 m.p.h. to 10 m.p.h. for the conditions stated above.



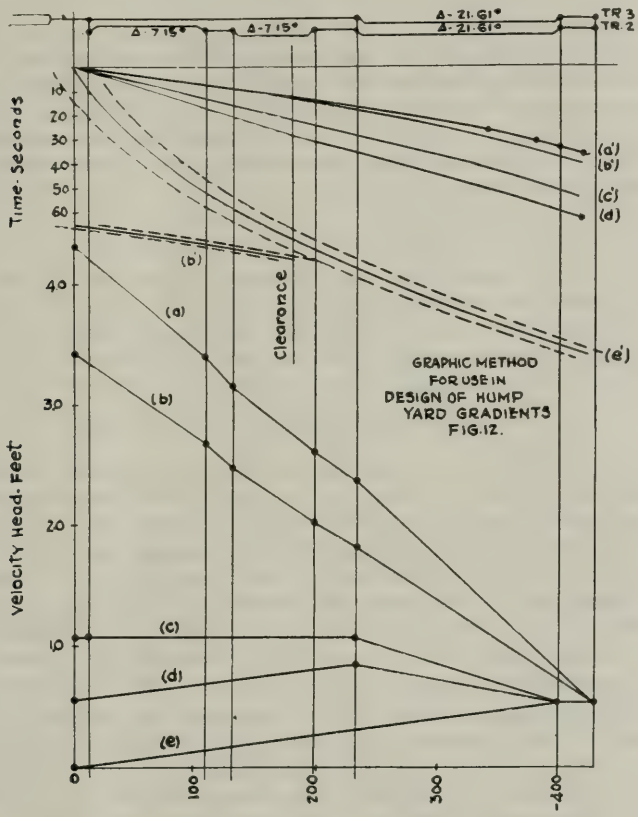
Method 2

This method viewed from the standpoint of releasing speeds is the same as Method 1.

Method 3

This method is a modification of Method 1 in that all tracks in the group are graded in the same plane as the track having the maximum curvature which requires that tracks 1 to 5, inclusive, have profiles the same as track 1, and that tracks 21 to 25,

inclusive, have profiles the same as tracks 21, 22 and 24. It is obvious that with the conditions named under Method 1 there would be more tracks where acceleration could take place, thereby requiring that the releasing speeds be lowered for a larger percentage of the cars handled.



Method 4

This method is a modification of Method 3 in that all tracks in the group are graded in the same plane as the track having the least curvature, which requires that tracks 1 to 5, inclusive, have profiles the same as tracks 3 and that tracks 21 to 25, inclusive, have profiles the same as track 23. With the conditions named under Method 1, the range of releasing speeds would include 0 m.p.h. (0.54 VH) to 11.2 m.p.h. (4.20 VH) for tracks 1 to 5, inclusive, and 2.5 m.p.h. to 10.6 m.p.h. (3.72 VH) for tracks 21 to 25, inclusive. When compared with Method 1, however, a low releasing speed would be required for a smaller percentage of the cars while a higher releasing speed would be required for a larger percentage of the cars.

Method 5

This method involves grading all tracks in the same plane as the track having the greatest curvature which requires that all tracks have profiles the same as track 1. It is

obvious that, with the conditions named under Method 1, there would be even more tracks than under Method 3 where acceleration could take place, thereby requiring a lower releasing speed for a still larger percentage of cars.

Method 6

This method involves grading all tracks in the same plane as the track having the least curvature which requires that all tracks have profiles the same as track 23. This is a modification of Method 4 and with the conditions named under Method 1 the range of releasing speeds would include 3.3 m.p.h. (0.54 VH) to 11.7 m.p.h. (4.57 VH). It will be noted that with this method there are no tracks where the releasing speed is required to be lower than 3.3 m.p.h. and that in comparison with Method 1 the highest releasing speed is increased only 1 m.p.h.

Method 7

The accelerative increment to be found in Formula B (see page 130, Vol. 33 of the Proceedings) thus far has been omitted. It is obvious, that a plus value, for the factor b, will decrease while a minus value will increase the releasing speed and that the use of this factor will have its greatest effect on the easy rolling car.

(II) TIME OR DISTANCE SPACING OF CARS

The humping capacity of any yard may depend upon the frequency at which cars may be released at the crest of the hump which, in turn, is limited by the time or distance spacing required at various locations within the switching area. A graphic representation of time consumed and distance traveled in running cars from the crest to clearance will show the locations where such limitations occur. It is obvious that, within the retarder area, the gradients and retardation can be coordinated so as to permit running all kinds of cars from the crest to entering the last retarder with approximately the same time interval for each car. However, after entering the last retarder considerable variation may occur since various releasing speeds are required.

Fig. 12 illustrates various conditions which may exist when running an easy rolling car to track 1 closely followed by a hard rolling car running to track 2 based on the assumption that each has consumed the same amount of time in running from the crest to the last retarder. Velocity head values, taken from Fig. 11, are plotted to a common base line to show a direct relation between several combinations of car resistances and gradients, as follows:

(a) Hard rolling car, (0.9 per cent or 18.0 pounds per ton) with curve resistance, running on a non-compensated gradient to track 2.

(b) Hard rolling car, (0.9 per cent or 18.0 pounds per ton) with curve resistance, running on a compensated gradient to track 2.

(c) Easy rolling car, (0.22 per cent or 4.4 pounds per ton) with curve resistance, running on a non-compensated gradient to track 3.

(d) Easy rolling car, (0.22 per cent or 4.4 pounds per ton) with curve resistance, running on a compensated gradient to track 3.

(e) Easy rolling car, (0.22 per cent or 4.4 pounds per ton) without curve resistance, running on a compensated gradient to track 3.

Time distance curves are calculated by scaling the average velocity heads for small increments of distance, converting them to speed values, dividing these values into the

distance increments, thus determining a time increment, and finally adding each time increment to the preceding total to be plotted in accordance with the distance traversed. Time distance curves (a′) to (e′) inclusive were plotted from corresponding velocity head profiles (a) to (e) inclusive.

The front and rear ends of a car shown for curve (e′) and for part of curve (b′) as it has been redrawn to show the relation between them at the clearance point for tracks 2 and 3 when the easy rolling car is stopped in the last retarder and then allowed to run to clear, and when the hard rolling car runs to track 2. It will be noted that for this condition, approximately a 65 second spacing between cars would be required to prevent cornering at the clearance point.

If the easy rolling car has curve resistance and runs as shown in (d′) the time spacing would be 18 seconds but if the gradients are non-compensated as shown in (a′) and (c′) the time spacing would be 12 seconds. Furthermore, if the clearance point is at a greater distance from the last retarder the time spacings for the above combinations are increased.

(III) Conclusions

No conclusions have been drawn from the above since this report is intended only to describe the graphic method, the special cases having been given to illustrate various applications which may be made. All of the special cases were based on this Committee's report, page 781, Vol. 31.

Appendix D

(5) SCALES USED IN RAILWAY SERVICE

H. M. Roeser, Chairman, Sub-Committee; J. E. Armstrong, H. G. Basquin, Alfred Bousfield, A. W. Epright, E. D. Gordon, M. J. J. Harrison, E. M. Hastings, H. O. Hem, E. K. Lawrence and E. P. Vroome.

PROPOSED SPECIFICATIONS FOR THE MANUFACTURE AND INSTALLATION OF MOTOR TRUCK, BUILT-IN, SELF-CONTAINED AND PORTABLE SCALES FOR RAILWAY SERVICE

Introduction

Motor truck, built-in, self-contained and portable scales for railway service of the kind known to the trade as knife-edge scales are covered by these specifications. The application is basically to scales equipped with weigh-beams. For scales of the automatic indicating and/or recording type, and with automatic indicating and/or recording attachments, the specifications apply to all parts except the mechanism essential to the automatic feature.

1. Information to be Supplied by Purchaser

To assure definiteness in handling proposals and acceptance of material when manufacturers or contractors are required to furnish scales, or are invited to offer bids to furnish scales conforming to the specifications herein, the information indicated in the schedule below must be supplied by the purchaser.

101. State the nominal capacity of the scale and the size of platform.
102. If a motor truck scale, is a plain or registering weigh-beam required?
103. If a built-in scale, is a full-capacity beam required?
104. If a built-in or self-contained scale and a definite ratio is required at the beam tip, state what it is. (See Item 1304.)
105. State the material of which the counterpoise weights are to be made. (See Item 1314.)

106. For motor truck and built-in scales, state what material is required for the platform.

107. If a motor truck scale, is the weigh-bridge to be furnished completely fabricated?

108. If a built-in scale, is the weigh-bridge, platform and coping material to be furnished with the scale?

109. For motor truck and built-in scales, state special requirements, if any, for clearance between the platform and weigh-beam.

110. What installation service, if any, is to be furnished by the firm supplying the scale?

2. Classes of Scales

201. The classes of scales covered by these specifications are the following:

(a) **Motor Truck Scales:** A motor truck scale is one designed for the purpose of weighing power-driven highway vehicles and trailers.

(b) **Built-in Scales:** A built-in scale is one of 10,000 or 20,000 pounds capacity, marketed without the frame supporting and containing the main lever system, designed to require preparation of a foundation on the premises where used.

(c) **Self-contained Scales:** A self-contained scale is one enclosed and supported by its own frame, marketed as a complete weighing unit and designed for use in a permanent location.

(d) **Portable Scales:** A portable scale is one mounted on wheels or otherwise designed for easy movement from place to place.

3. Capacities and Sizes

301. **Definitions.**

(a) **Capacity:** The capacity of a scale is the heaviest load that can be totally applied to the platform without inducing stresses in any member in excess of those specified in Section 5, the conditions of concentration of loading being those required in Section 6.

(b) **Nominal Capacity:** The nominal capacity of a scale is the largest weight indication obtainable by use of all the reading elements in combination, fractional beams totaling two per cent or less of the remaining reading elements being neglected.

(c) **Size:** The size of a scale is expressed by the dimensions of the platform surface. In rectangular platforms, the first dimension given is that of the platform edge nearest the beam.

302. **Nominal Capacities and Sizes:** The nominal capacities and sizes of scales in the different classes covered by these specifications shall be as given in Tables 1-(a) and 1-(b).

TABLE 1—(a)

NOMINAL CAPACITIES AND SIZES OF MOTOR TRUCK SCALES FOR RAILWAY SERVICE

Nominal Capacity (pounds)	*Size (feet)*	*Conditions governing selection*
60,000 to 70,000	34 by 10	For weighing coupled vehicles.
40,000 to 60,000	22 by 9	Usual standard for weighing separate vehicles.

Special cases may be better suited by selection from the following nominal capacities and sizes.

60,000	24 by 10.
40,000 to 60,000	20 by 9, 20 by 10, 24 by 9, 24 by 10.
36,000	18 by 9.
24,000	16 by 8.

TABLE 1—(b)

NOMINAL SIZES AND CAPACITIES OF BUILT-IN, SELF-CONTAINED AND PORTABLE SCALES FOR RAILWAY SERVICE

Class of Scale	*Nominal Capacity (pounds)*	*Size (feet)*
Built-in	10,000	6 by 5, 8 by 6, 9 by 7
	20,000	8 by 6, 9 by 7
		(inches)
Self-contained	2,500	46 by 38
	4,000	48 by 48
	10,000	72 by 54
Portable	1,000	18 by 27
	2,000	25 by 32

(In Tables 1—(a) and 1—(b), the intent of the specifications is that minor variations from the nominal capacities and dimensions given for platform sizes are immaterial, and being otherwise in conformance with these specifications, the usually manufactured stock sizes are satisfactory.)

4. Plans

401. The purchaser shall, upon his request, be furnished written information showing the material of which scales proposed to be furnished are made, and if any material be not among those to which the safe stresses listed in Section 5 apply, the chemical and physical properties must be given in sufficient detail to permit confident judgment of the safe stresses or factors of safety used in design.

402. For motor truck and built-in scales, the purchaser shall be furnished assembly plans showing the location and size of open holes for field connections and all information necessary for the design and construction of the pit or all parts required and not furnished with the scale. (See also Item 1701.) Upon request in the invitation for bids, the purchaser shall be furnished drawings or descriptions in sufficient dimensional detail to permit the customary design calculations for stresses and to allow adequate checking of the design requirements for construction, finish and workmanship.

5. Design Data, Working Stresses, and Formulas

501. In any scale loaded as required in Section 6, the following unit stresses shall not be exceeded. The stresses given include a sufficient allowance for impact.

TABLE 2

WORKING STRESSES IN POUNDS PER SQUARE INCH

Material	*Transverse Bending*		*Direct Stress*		*Shear and Torsion*
	Tension	*Compression*	*Tension*	*Compression*	
Cast Iron (gray), Thickness of section.					
0.25″	5000	8500	3500	10000	5000
0.3	4780	8130	3350	9560	4780
0.35	4600	7820	3220	9200	4600
0.4	4450	7560	3110	8900	4450
0.45	4320	7340	3020	8640	4320
0.5	4200	7140	2940	8400	4200
0.6	4020	6830	2810	8040	4020
0.7	3870	6580	2710	7740	3870
0.8	3740	6360	2620	7480	3740
0.9	3630	6170	2540	7260	3630
1.0	3540	6020	2480	7080	3540
1.1	3450	5860	2410	6900	3450
1.2	3380	5750	2370	6760	3380
1.3	3310	5620	2320	6620	3310
1.4	3250	5520	2270	6500	3250
1.5	3190	5420	2230	6380	3190

TABLE 2.—Continued

Material	Transverse Bending Tension	Transverse Bending Compression	Direct Stress Tension	Direct Stress Compression	Shear and Torsion
Cast Iron (gray), Thickness of section.					
1.6	3140	5340	2200	6280	3140
1.8	3050	5180	2130	6100	3050
2.0	2970	5050	2080	5940	2970
2.5	2810	4780	1970	5620	2810
3.0	2690	4570	1880	5380	2690
3.5	2580	4390	1810	5160	2580
4.0	2500	4250	1750	5000	2500

In designing cast iron members to sustain stress of any character, the maximum allowable unit stress of any character shall be determined by the greatest thickness, exclusive of fillets, of the portion of the section carrying the stress being considered. In the main portion of a beam the thickness of the web or flange shall be used whichever is the greater. The thickness of the flange shall be considered either as the average depth of the outstanding portion or the breadth of flange outside to outside, whichever is less.

Cast Iron (Semi-Steel). See Item 502.					
Steel					
Castings	8000	10000	8000	10000	5000
Machine	12000	12000	12000	12000	7500
Pivots and Bearings,					
High Carbon, Hardened	24000	24000	24000	24000	
Special Alloy, Hardened	30000	30000	30000	30000	

Steel Structural	For Live Loads and Lateral Forces	For Dead Loads
Tension, axial (net section), transverse bending, and diagonal in webs of girders and rolled beams where maximum shear and bending simultaneously occur	12,000	24,000
Bolts, area at root of threads	7,500	15,000
Compression, axial and transverse bending	12,000	24,000
Shear, girder webs, gross section	7,500	15,000
Pins and shop driven rivets	9,000	18,000
Turned bolts and power driven field rivets	7,500	15,000
Unfinished bolts and hand driven rivets	6,000	12,000
Bearing, pins, steel parts in contact, and shop driven rivets	18,000	36,000
Turned bolts and power driven field rivets	15,000	30,000
Unfinished bolts and hand driven rivets	12,000	24,000
Rollers (lb. per lin. in.), where d is the roller diameter in inches	450 d	900 d

In proportioning rivets, nominal diameters shall be used.

The effective bearing area of a pin, bolt or rivet is the diameter of the member multiplied by the thickness of the metal upon which the member bears.

In metal ⅜ in. thick and over, half the depth of countersink shall be omitted in calculating bearing area. In metal less than ⅜ in. thick, countersunk rivets shall not be assumed to carry stress.

Timber (used only for flooring and spiking strips), see Item 514 and Section 24.

502. **Cast Iron (Semi-Steel):** For the purposes covered by these specifications, castings of iron containing 18 per cent or more of steel are designated as semi-steel castings. For the corresponding thickness of section and nature of stress, the working stresses for semi-steel shall be 1.6 times those given in Table 2 for gray cast iron.

503. **Knife-edge Bearing Stresses:** The load per linear inch of knife-edge shall not exceed 5,000 pounds for high carbon steel and 6000 pounds for special alloy pivot steel.

504. **Concrete Bearing Stresses:** The stress to be allowed for bearing on concrete shall not exceed 300 pounds per square inch.

505. **Projecting Pivots—Formula for Stresses:** Where practicable, the pivots shall be supported their full length by integral parts of the lever. Where impracticable so to support the pivots, external bending moments shall be determined as follows:

Let M be the required bending moment in inch-pounds,
L, the length in inches of the moment arm,
W, the total lead in pounds on both ends of a pivot,
D, the length in inches of bearing in the loop,
T, the distance in inches between friction faces of the loop,
B, the width in inches of the boss or sustaining member enveloping the pivot

Then

$$L = D/2 + (T - B) + 1/4''$$

And

$$M = WL/2$$

506. **Stringers, Floor Beams, and Floor Slabs:** When loads are, or may be applied to the scale platform from any direction, the following principles of design applicable to stringers, floor beams, and floor slabs shall be used. If, for any reason of design or installation, traffic over the scale is constrained to follow within definite limits a given direction, the stringer and floor beam sections, and the flooring, may be calculated to conform to the established traffic conditions.

507. **Shears and End Reactions in Stringers and Floor Beams:** In calculating end shears and end reactions in transverse floor beams and longitudinal beams and stringers, no lateral or longitudinal distribution of the vertical concentrated live loads shall be assumed.

508. **Bending Moment in Stringers:** In calculating bending moments in longitudinal beams or stringers, no longitudinal distribution of the loads shall be assumed. The lateral distribution shall be determined as follows:

(a) **Interior Stringers:** Interior stringers shall be proportioned for leads determined in accordance with the following table, except that when the limiting stringer spacings are exceeded, the stringer loads shall be determined by the reactions of live loads, assuming the flooring between stringers to act as a simple beam.

Kind of Floor	*Fraction of Wheel Load to Each Stringer*	*Limiting Stringer Spacing in Feet*
Plank	S/4.0	4.0
Strip 4 in. in thickness or wood block on 4-inch plank sub-floor	S/4.5	4.5
Strip 6 in. or more in thickness	S/5.0	5.0
Concrete	S/6.0	6.0

S = spacing of stringers in feet.

(b) **Outside Stringers:** The live load supported by outside stringers shall be the reaction of truck wheels, assuming the flooring to act as a simple beam between stringers.

(c) **Total Capacity of Stringers:** The combined load capacity of the beams in a panel shall not be less than the total live and dead load on the panel.

509. **Bending Moment in Floor Beams:** In calculating bending moments, no transverse distribution of loads shall be applied.

If longitudinal stringers are omitted and the floor is supported directly on the floor beams, the latter shall be proportioned for a fraction of the concentrated live loads as indicated in Item 508-(a), substituting "floor beams" for "stringers", except that when the limiting floor beam spacing is exceeded the floor beam loads shall be determined by the reactions of the loads, assuming the flooring between floor beams to act as a simple beam.

510. **Distribution of Wheel Loads on Concrete Slabs: Bending Moment:** In calculating bending stresses due to wheel loads on concrete slabs, no distribution in the direction of the span of the slab shall be assumed. In the direction perpendicular

to the span of the slab, the wheel load shall be considered as distributed uniformly over a width of slab which is termed the "effective width" and is obtained from the following formulas in which

S is the span of slab in feet
W is the width of tire in feet
D is the distance in feet from the center of the near support to the center of wheel, and
E is the "effective width" in feet for one wheel.

Case I—Main reinforcement parallel to direction of traffic:

$E = 0.7\,S + W$, in which E shall have a maximum value of 7.0 feet.

When two wheels are so located on a transverse element of the slab that their effective widths overlap, the "effective width" for each wheel shall be $\frac{1}{2}\ (E + C)$, in which E is the value determined by the formula above and C is the distance between centers of wheels.

Case II—Main reinforcement perpendicular to direction of traffic.

$E = 0.7\ (2D + W)$.

For this case, the bending moment on a strip of slab one foot in width shall be determined by placing the wheel loads in the position to produce the maximum bending, assuming no distribution; determining the effective width for each wheel; and assuming the load of each wheel on the one-foot strip to be the wheel load divided by its respective effective width.

The design assumption of Case II does not provide for the effect of loads near unsupported edges. Therefore, at locations where the continuity of the slab is broken, the edges of the slab shall be supported by diaphragms or other suitable means.

511. **Shear in Slabs:** Slabs designed for bending moment in accordance with the foregoing rules and for the wheel loads contemplated by these specifications may be considered adequate for shear without special reinforcement.

512. **Placing of Reinforcement:** The minimum clear distance between parallel bars shall be 1½ times the diameter of round bars, or 1½ times the diagonal of square bars. The maximum spacing shall be 2½ times the slab thickness. Bars parallel to the face of any member shall be imbedded a clear distance of not less than one inch from the face.

513. **Members Supporting Deck Overhang:** In calculating bending moments, and shears and reactions in members supporting the flooring outside the main girders, no lateral or longitudinal distribution of the vertical live loads shall be assumed.

514. **Floor Plank:** In motor truck and built-in scales when plank is used for platform covering, the thickness shall not be less than ⅛ the distance between spiking strips or members to which the plank is securely fastened, provided that in no instance shall the thickness be less than three inches. In motor truck scales, the width shall not be less than eight inches.

515. **Bearing Pressures: Soil and Rock:** The bearing areas of the foundation footings shall be such that the bearing pressure on the soil, under the worst condition of loading, will not exceed—

For fine sand or clay	4,000 lb. per sq. ft.
For coarse sand and gravel or hard clay.....	6,000 lb. per sq. ft.
For boulders or solid rock	20,000 lb. per sq. ft.

If the soil has not a safe bearing capacity equal to that of fine sand or clay, its bearing capacity shall be increased by drainage, by adding a layer of gravel or broken stone, or by driving piles.

516. **Platform Overturning Moments:** In all scales, when calculating moments tending to overturn or tip platforms, no distribution of vertical live loads shall be assumed. (See Item 2401.)

6. Particulars of Loading

601. **General:** All parts of scales shall be proportioned for the following loads and forces:

(a) Dead load.
(b) Live load.
(c) Impact, or dynamic effect of live load.
(d) Lateral forces.
(e) Longitudinal forces.

602. **Dead Load:**

(a) The dead load shall be considered in the design of motor truck scales. It shall be taken as the weight of all parts supported by the main lever load pivots.

(b) The unit weights in Table 3 shall be used in computing dead load.

TABLE 3

UNIT WEIGHTS OF MATERIAL FOR USE IN COMPUTING DEAD LOADS

Material	*Weight per Cubic Foot*
Steel—Use handbook values or	490
Cast Iron	450
Timber, treated or untreated	60
Concrete, plain or reinforced	150
Pavement, other than wood block	150

603. **Live Load:**

(a) **Motor Truck Scales:** For the design of motor truck scales, the loading shall be assumed to be the sequence of moving, concentrated loads listed in Table 4.

TABLE 4

SCHEDULE OF LIVE LOADS FOR MOTOR TRUCK SCALES

(a) For scales of 20,000 lb. nominal capacity with 16′ by 8′ platform, 30,000 lb. nominal capacity with 18′ by 9′ platform, and 60,000 lb. nominal capacity with 24′ by 10′ platform; one two-axle vehicle with wheelbase of 168 inches and wheels 72 inches apart, center to center; gross weight of vehicle equal to nominal capacity of scale, 90% of which is assumed to be concentrated on rear axle and 50% on one rear wheel of vehicle.

(b) For all other sizes and capacities listed in Table I-(a):

Axle	*Axle Load (wheels spaced 72 in. apart, center to center) (pounds)*	*Distance center to center of following axle (inches)*
1	6,000	168
2	16,000	40
3	16,000	100
4	16,000	40
5	16,000	

The combined live and dead loads to be used in design of parts shall be as listed in Table 5 (see also Item 604).

TABLE 5

COMBINED LIVE AND DEAD LOADS TO BE USED IN THE DESIGN OF MOTOR TRUCK SCALES

(These loads are to be used for the design of parts made of materials for which the safe stresses given in Section 5 herein contain provision for impact.)

Note 1.—The "corner load" is the maximum reaction possible at any main load pivot.

Note 2.—The "end load" is the maximum reaction at the two main load pivots at the same end of the scale.

Platform Covering	*Corner Load (pounds)*	*End Load (pounds)*	*Total Load (pounds)*
(Scales of 24,000 lb. nominal capacity with 16′ by 8′ platform.)			
Plank or Steel Plate	13,000	24,900	30,600
Concrete	14,400	27,600	36,100
(Scales of 36,000 lb. nominal capacity with 18′ by 9′ platform.)			
Plank or Steel Plate	21,200	37,400	45,100
Concrete	23,000	40,925	52,200

TABLE 5 (Continued)

Platform Covering	*Corner Load (pounds)*	*End Load (pounds)*	*Total Load (pounds)*
(Scales of 40,000 lb. to 60,000 lb. nominal capacity with 20′ by 9′ platform.)			
Plank or Steel Plate	23,800	43,300	75,300
Concrete	25,700	47,800	83,100
(Scales of 40,000 lb. to 60,000 lb. nominal capacity with 20′ by 10′ platform.)			
Plank or Steel Plate	25,700	43,300	76,200
Concrete	27,900	47,800	84,900
(Scales of 40,000 lb. to 60,000 lb. nominal capacity with 22′ by 9′ platform.)			
Plank or Steel Plate	25,400	46,200	76,500
Concrete	27,600	50,500	85,100
(Scales of 40,000 lb. to 60,000 lb. nominal capacity with 24′ by 9′ platform.)			
Plank or Steel Plate	26,800	49,100	77,800
Concrete	29,100	53,800	87,100
(Scales of 40,000 lb. to 60,000 lb. nominal capacity with 24′ by 10′ platform.)			
Plank or Steel Plate	28,800	49,700	79,000
Concrete	31,500	55,100	89,800
(Scales of 60,000 lb. nominal capacity with 24′ by 10′ platform.)			
Plank or Steel Plate	39,800	64,000	75,600
Concrete	42,300	69,200	85,800
(Scales of 60,000 lb. to 70,000 lb. nominal capacity with 34′ by 10′ platform.)			
Plank or Steel Plate	34,800	61,000	92,700
Concrete	38,500	68,300	107,400

(b) **Built-in Scales:** In built-in scales the design shall provide for two live loads totaling the capacity of the scale, spaced apart equal to the shortest distance between two main lever load pivots, so located on the deck and so relatively proportioned as to cause the greatest stress in the member being designed. The maximum value of the greater of the two live loads shall be

$$L = 0.75\,W - 0.25\,D$$

and the minimum

$$L = 0.50\,W$$

wherein W is the scale capacity
D is the dead load.

(c) **Self-contained and Portable Scales:** In self-contained and portable scales, the design shall provide for a condition of live loading consisting of two equal loads totaling the scale capacity, spaced apart equal to the diagonal distance between main lever load pivots and so located as to cause greatest stress in the member being designed. Except in instances where, for some special reason, the design includes dead load features not regularly catalogued or comprised in the model of scale, the dead load may be neglected.

604. **Impact:** In the design of scales covered by these specifications, when stresses are used not greater than the "Working Stresses", Table 2, Section 5, herein, no increase need be made to vertical live loads, or need any other allowance be considered to provide for the effects commonly included under the general term "Impact".

605. **Lateral Forces.**

(a) **Motor Truck and Built-in Scales:** The weigh-bridges of motor truck and built-in scales shall be designed for a lateral live load concentrated at the center of the span, equal to 20% of the capacity plus 100 pounds per foot of span.

(b) **Self-contained and Portable Scales:** In self-contained and portable scales, provision shall be made for the effect of a lateral force of 1000 pounds and 500 pounds, respectively, acting in the plane of the deck and in a vertical plane through the transverse center line.

606. **Longitudinal Forces:**

(a) **Motor Truck and Built-in Scales:** In motor truck and built-in scales, provision shall be made for the effect of a longitudinal force of 10% of the capacity of the scale acting four feet above the plane of the deck and in a vertical plane through the longitudinal center line.

(b) **Self-contained and Portable Scales:** In self-contained and portable scales, provision shall be made for the effect of a longitudinal force of 1000 pounds and 500 pounds, respectively, acting in the plane of the platform and in a plane through the longitudinal center line.

7. Scale Levers

701. **Type:** Levers with truss rods will not be permitted.

702. **Qualities of Castings:** Cast pieces used for levers shall not be warped. They shall be clean, smooth, uniform, and free from blisters, blowholes and shrinkage cracks.

703. **Machined Ways for Nose Irons:** In motor truck scales, levers that are to be equipped with nose irons shall have those portions of the lever ends receiving them machined for the full distance over which the nose irons are to move.

704. **Nose Iron Guides:** The guides for all nose irons shall be such that when one is moved for the purpose of adjustment, the pivot will be held parallel to its original position.

705. **Leveling Lugs:** In motor truck scales and built-in scales of the straight lever type, each lever shall be provided with leveling lugs for longitudinal alinement; for torsion levers, leveling lugs shall be provided on the pipe or torsion member for transverse alinement, and on the extension arm for longitudinal alinement. Each pair of lugs shall be spaced 11 inches. The leveling surfaces of each pair of lugs shall be finished to a common plane parallel to the plane established by the knife-edges of the end pivots.

706. **Marking of Levers:** In motor truck scales, figures denoting the ratio of each lever shall be cast or otherwise permanently marked on the lever.

8. Pivots and Bearings

801. **Material:** The material used for pivots and bearings in scales covered by these specifications shall be either—

(a) Special alloy pivot steel (S.A.E. No. 6195), hardened to Rockwell C scale not less than 58, or

(b) Carbon steel (S.A.E. No. 1095), hardened to Rockwell C scale not less than 60.

802. **Design:** In motor truck scales and built-in scales, all pivots shall be so designed and manufactured that the included angle of the sides forming the knife-edge will not exceed 90 degrees, and the offset of the knife-edge as referred to the center line of the pivot will not exceed 10% of the width of the pivot for "machined in" pivots and 15% of the width of the pivot for "cast in" pivots.

803. **Fastening:** All pivots shall be firmly fastened in position without swedging or caulking.

804. **Continuous Contact:** All pivots shall be so mounted as to secure equal and continuous contact of the knife-edges with their respective bearings for the full length of the parts designed to be in contact; in loop bearings, the knife-edges shall project slightly beyond the bearings in the loops.

805. **Position:** In any lever, pivots shall be so mounted that—

(a) Each knife-edge will be maintained in a horizontal plane under any load within the capacity of the scale.

(b) A plane bisecting the angle of a knife-edge will be perpendicular to the plane through the knife-edges of the end pivots.

(c) In motor truck and built-in scales, the actual distance between the end knife-edges of any lever does not differ from the nominal distance by more than 1/64 inch per foot.

806. **Support for Projecting Pivots:** The reinforcing on the levers to support projecting pivots shall be tapered off to prevent accumulation of dirt next to the pivots and to provide proper clearances.

807. **Design of Bearings:** Bearings and the parts supporting or containing them shall be so applied to the mechanism that permissible movement of the platform will not displace the line of contact between any bearing and the opposing pivot.

808. **Mounting of Bearing Steels:** All bearing steels of the same nominal dimensions or parts identification shall be interchangeable or mounted in interchange-

able bearing blocks. The interchangeable part shall be securely mounted in the part containing it.

809. **Finish of Bearing Steels:** The bearing surfaces shall be brought to a smooth, true and accurate finish to insure continuity of contact with opposing pivots.

9. Nose Irons

901. **Design and Fastening:** Nose irons shall be constructed so that they may be fastened in proper position by means of U. S. Standard screws or bolts, or other equally effective mechanical device.

(a) **Design of Fastening:** The device for clamping the nose irons in position shall be of such design that indentations in the lever will not be made, and for motor truck scales and built-in scales it shall be independent of any means provided for adjustment.

(b) **Direction of Fastening:** The devices for fastening nose irons shall be so designed that loads applied to the scale will not cause tension in the fastening bolts. For motor truck and built-in scales, clamping devices shall hold nose irons against levers in the same direction they would be forced by the load, and shall be such that any nose iron will remain in place when the clamping device is released.

(c) **Control of Nose Iron Movement:** The movement of the nose irons shall be controlled by means of adjusting screws of U. S. Standard size and thread. For motor truck scales, these screws shall be made of non-corrosive material.

902. **Marking of Position:** The position of each nose iron as determined by the factory adjustment shall be accurately, clearly and permanently indicated by a well-defined mark on the lever and nose iron, which shall meet on a common line.

903. **Finish and Pivot Mounting:** Those surfaces of the nose iron intended to come into slidable contact with the levers shall be made true so as to secure an accurate fit of the nose irons on or in the levers. Each nose iron shall be of such design that when adjustments are made the knife-edge will be held parallel to its original position.

10. Loops and Connections

1001. **Design Proportion:** Loops which form bearings for projecting pivots may be of any type, provided the clearance between the enclosed pivots and the body of the loop is at least one-fourth inch.

1002. **Length:** All loops of like connections shall be of the same length.

1003. **Vertical Adjustment:** Means for vertical adjustment shall be provided between the lever system and the beam, which will permit independent leveling of the shelf lever when one is used. When no shelf lever is used, the connection to the beam shall be adjustable. Screw adjustments shall be provided with lock nuts or equivalent device.

11. Lever Fulcrum Stands

1101. **Qualities of Castings:** Castings for lever stands shall be clean, smooth, uniform, and free from blisters, blowholes and shrinkage cracks.

1102. **Position on Bases:** The upright portion of any stand shall be so placed on its base that the resultant line of forces applied through the bearing carried by the stand falls within the middle third of the length and width of the base.

1103. **Bases for Lever Stands:** The base of any lever stand shall be smooth, or shall be finished in any suitable manner true within a tolerance of $\frac{1}{32}$ inch to a plane perpendicular to a vertical line through the center of the knife-edge bearing carried by the upright portion of the stand.

1104. **Finish of Tops of Stands:** The top of any lever stand for receiving a bearing steel, cap or block shall be finished to a tolerance of $\frac{1}{32}$ inch of a plane parallel to the base.

1105. **Anchor Bolt Holes:** For built-in scales of the A-lever type, one anchor bolt hole 1½ inches in diameter shall be provided in the base of each stand. In all other scales, two or more anchor bolt holes, 1½ inches in diameter, shall be provided in the base of each stand unless other equally effective means for anchorage is provided.

12. Checks

1201. **Type:** The weigh-bridges, or platforms, of all scales shall be equipped with devices which effectively restrict motion in any horizontal direction, so designed and constructed as to withstand adequately the horizontal forces prescribed in Items 605 and 606. For motor truck and built-in scales, if checks of either the rod or bumper type are used, they shall be adjustable.

13. Weigh-Beams and Accessories

1301. **Capacity to be Marked:** The capacity of the scale as defined in Item 301–(a) shall be explicitly and conspicuously marked on or near the beam.

1302. **Requirement for Nominal Capacity:** The nominal capacity as defined in Item 301–(b) shall not exceed the scale capacity.

1303. **Type of Beam:**

(a) **Motor Truck Scales:** Full-capacity beams shall be used with motor truck scales. The arrangement may be such that the entire tare weight can be set up independently of the main beam, or the beam bar used for the determination of the net lading, provided (1) Tare beams or bars shall not be used with registering beams; (2) the sum of the weights determinable on the tare weight and net weight or main beams shall not conflict with the definitions and requirement in Items 301 and 1302; and (3) when tare beams are furnished, the graduations of the principal and fractional bars shall comply with the specifications given for the main beam. (See Item 1306)

(b) **Other than Motor Truck Scales:** At the option of the purchaser, a full-capacity beam with tare weight bar, or double or single beam with counterpoise weights shall be furnished with built-in, self-contained and portable scales.

1304. **Ratio:** A pivot and loop shall be provided at the beam tip. For other than motor truck scales, the ratio at the beam tip pivot shall be—

For built-in scales	500 or 1000
For self-contained scales	200 or 300
For portable scales	100

For all scales, the ratio to the beam butt pivot shall be plainly and permanently stamped on the beam.

1305. **Poise Stop:** In all scales, each beam bar shall be provided with a stop to prevent movement of the beam poise back of the zero notch or graduation.

1306. **Notches:** On main beams the notches shall not be spaced closer than six to the inch. Each notch shall be so made that when the pawl rests in it, a line projected from the center of the side of the notch nearer the zero graduation to the axis about which the pawl stem rotates will be perpendicular to that side of the notch.

(a) In motor truck scales, the value of each notch on the main beam shall be 1,000 pounds.

1307. **Pawl or Latch:** The tip of the pawl or latch shall be of the same width as the notches of the beam and shall be rounded so that a small amount of foreign material in the bottom of the notch will not prevent the poise from assuming its correct position when the pawl is dropped in the notch.

1308. **Projections or Recesses:** Poises shall be designed with the object of reducing to a minimum the number of projections and recesses that will retain foreign material.

1309. **Poise Bearings:** Each poise shall be constructed to move along its beam without side play. In full-capacity beams, the main poises shall be equipped with roller or other form of frictionless bearing.

1310. **Fractional Beams:** The fractional poise on a full-capacity registering beam shall be constructed to stop positively at each graduation and to prevent movement beyond the last graduation. In motor truck scales, the last registration of the fractional poise shall be 990 pounds, and in built-in and self-contained scales, 98 pounds or 95 pounds.

1311. **Operating Lever:** On registering beams, a substantial type of hand grip shall be provided to facilitate the registration of the weight. The natural operation of the registering mechanism shall not cause lateral displacement of the beam.

1312. **Receptacle for Weight Ticket:** On registering beams, means shall be provided to prevent placing the weight ticket in its receptacle in any position in which a weight can be registered different from that represented by the poise setting.

1313. **Balance Ball:** For motor truck scales, the position of the balance ball shall be vertically adjustable. Longitudinal movement shall be controlled by means of a self-contained hand-operated screw or other device which will not require the ball to

be rotated in making adjustments. Means for locking the ball in position shall be provided.

1314. **Poises and Counterpoise Weights:**

(a) **Material:** Counterpoise weights and the exterior shell of poises shall be made of non-corrosive alloys, steel, iron, brass, or any other metal or alloy of metals not softer than brass. Poises shall have no metal softer than brass making contact with the beam.

(b) **Corrosion Protection:** Weights made of corrosive material, such as cast iron or steel, shall be protected from corrosion by the application of a durable chemical coating.

(c) **Surface and Form:** Weights shall be smooth, without sharp points or corners, and of such form that the minimum surface consistent with convenience of use will be exposed to wear or corrosion.

(d) **Adjusting Cavities:** All cavities for adjusting material shall be formed in the top or sides of counterpoise weights, and shall be of such form that the adjusting material will be permanently and securely retained. The adjusting material shall not project beyond the surface of the weight and, if in the top of the weight, the material closing the cavity shall be not more than 0.04 inch below the surface.

(e) **Movable Parts:** All movable elements forming a part of a poise shall be so constructed as not to be detachable without manifest mutilation of the poise. Set screws, if used to secure a poise at any point on a beam, shall not be removable.

(f) **Marking:** All counterpoise weights shall be clearly marked with their nominal weight, i.e., 1 lb., 2 lb., etc., and also with the value they represent when used upon the scale for which they are intended.

(g) **Sealing:** After the weights are adjusted to their proper value, all caps or plugs closing adjusting cavities shall receive the impression of a seal, appropriate in character or design, to attest the factory adjustment, if made at the factory of the manufacturer; or, if readjusted elsewhere, the seal shall be such as to indicate where the adjustment was made.

(h) **Counterbalance Weights:** If counterbalance weights are to be used, the lower end of the hanger stem shall be threaded; a cup for the loose balancing material shall be screwed to the lower end of the stem; and each additional weight shall be provided with an elongated hole in the center through which the hanger stem may pass. No slotted counterbalance weights are to be used. When no counterbalance weights are necessary on top of the counterbalance cup, the cavity shall be closed by a cover secured in a positive manner. No counterbalance weights shall be used in any place in the scale except at the beam.

(i) **Tolerances:** The manufacturer's tolerances, or the tolerances to be allowed on new counterpoise weights and the tolerances which shall apply on readjusting the weights shall be no greater than the values in the following table.

TABLE 6

TOLERANCES ON NEW OR NEWLY ADJUSTED COUNTERPOISE WEIGHTS FOR MULTIPLYING LEVER SCALES

(Avoirdupois System)

Weight (pounds)	*Ratio 100:1 and less than 1000:1* (grains)	*Ratio 1000:1 and over* (grains)
15	8.0	4.0
10	8.0	4.0
8	6.0	3.0
5	6.0	3.0
4	4.0	2.0
3	4.0	2.0
2	3.0	1.5
1	2.0	1.0
(ounces)		
10	2.0	1.0
8	1.0	0.5
5	1.0	0.5
4	1.0	0.5

1315. **Identification of Parts:** A serial number shall be stamped on the front of each complete beam.

1316. **Type Figures:** On type registering beams, type figures shall be made of material sufficiently hard that, under the designed conditions of use, the figures will not become battered or defaced. The figures shall be plain and raised sufficiently high to insure a clear impression upon the weight ticket or tape. They shall be so attached that they cannot become loosened or detached without a positive indication that the beam is out of order.

1317. **Beam Fulcrum Stands:** The upright portion of any beam fulcrum stand shall be so placed on the base that for any position of the beam in the normal weighing operation the line of resultant force through the fulcrum knife-edge will pass through the middle third of the length and width of the base.

(a) **Motor Truck Scales:** For motor truck scales the beam shall not be suspended. It shall be supported on a stand provided with compensating bearings.

1318. **Trig Loops:**

(a) **Material:** Trigs made of non-magnetic material shall be provided with beams made of magnetic material.

(b) **Play of the Beam:** The vertical movement of the beam in the trig loop shall not be less than that given in Table 7.

TABLE 7

MINIMUM VERTICAL MOTION OF WEIGH-BEAMS IN TRIG LOOPS

Length of Beam (Distance from fulcrum to trig loop)	Minimum Vertical Motion in Trig Loop
Under 12 inches	0.4 inch
Over 12 inches, including 20 inches	0.5 "
Over 20 inches, including 40 inches	0.7 "
Over 40 inches	0.9 "

1319. **Beam Support:** In portable scales the pillar supporting the beam shall be rigid. In other scales the beam fulcrum stand and trig loop stand shall be securely fastened to a shelf sufficiently strong and so supported that it will not deflect to an extent affecting the weighing performance.

14. Anti-Friction Points and Plates

1401. Anti-friction contacts shall be used to limit longitudinal displacement between knife-edges or pivots and their bearings. They shall be smooth and so designed as to provide contact at a point on the line of the knife-edge of pivots. For motor truck and built-in scales they shall be of hardened steel.

15. Clearances

1501. The clearance around and between the fixed and live parts of the lever system of motor truck scales shall be at least three-fourths (¾) of an inch, and for built-in and self-contained scales the clearance shall be not less than three-eighths (⅜) of an inch. The total clearance between anti-friction points on levers and stands shall be not less than one-sixteenth ($\frac{1}{16}$) of an inch nor greater than one-eighth (⅛) of an inch.

16. Factory Adjustments

1601. **Levers:** The design, workmanship and factory adjustment of the levers and beam shall be such that the proper ratio of the lever arms will be maintained.

17. Interchangeability

1701. Like parts of all like motor truck and built-in scales of the same design and manufacture shall be interchangeable unless otherwise herein specified. The scale drawings and the parts of the scale shall be marked to indicate the proper positions of the parts in the scale.

18. Sensibility Reciprocal (SR)

1801. **Definition:** The sensibility reciprocal is the weight required to be added to or removed from the scale platform to turn the beam from a position of equilibrium in the center of the trig loop to a position of equilibrium at either limit of its travel.

19. Tolerances

1901. **Errors:** The tolerance on errors in excess or deficiency for motor truck, built-in, self-contained and portable scales when tested upon the site of use and before being accepted as satisfactory weighing machines, shall be 0.10% of the applied load consisting of test weights of known value; provided (1) the tolerance shall not be less than one-half the minimal beam graduation on the scale being tested; and (2) a purchaser may by stipulation in the purchase order require scales on the same condition of test to meet tolerances not less than one-half, respectively, of the tolerances given above before accepting delivery.

1902. **Sensibility Reciprocal:** For the same classes of scales and the same conditions of test stipulated in Item 1901, the sensibility reciprocal shall not exceed the value of the minimal beam graduation.

20. Location and Elevation

2001. **Location:** Motor truck, built-in and self-contained scales shall be so located that an adequate foundation and a straight approach in line with the scale platform and of a length in excess of that of the longest vehicle to be weighed can be provided.

2002. **Elevation:** The scale platform shall be raised to such an elevation that the drainage of surface water will be away from it and, unless space will not permit it, the approaches shall be level, or nearly level, and paved for a length equal to that of the scale platform.

21. Foundations

2101. **Material:** Scale foundations resting upon or extending into the ground shall be constructed of concrete. (See Item 515).

2102. **Dimensions of Pit:** For motor truck and built-in scales, the size of the pit shall be such as to give a vertical clearance between the scale levers and the finished floor of the pit of not less than two (2) feet, and a horizontal clearance between the face of the pit walls and the scale parts below the platform, or below the weigh-bridge girders, if any, and above the bases of the stands, of not less than four (4) inches for motor truck scales and 1½ inches for built-in scales.

2103. **Walls of Pit:** The walls of the pit shall have a thickness at the top of not less than twelve (12) inches for motor truck scales, and not less than eight (8) inches for built-in scales.

2104. **Waterproofing:** When necessary, the pit shall be waterproofed.

2105. **Wall Batter:** All wall surfaces next to earth subject to freezing shall be constructed with a uniform batter of not less than one (1) inch to the foot, and as much more as necessary to permit the heaving of adjacent ground by frost action without disturbing the walls.

2106. **Pit Floors and Lever Stand Piers:** The concrete piers supporting the lever stands shall be not less than nine (9) inches deep, but shall in any case be carried to proper foundation. Their tops shall be above the floor of the pit a distance sufficient to prevent the accumulation of water under the bases of the stands, and they shall be finished to exact level and elevation to receive the lever stands. The floor of the pit may be designed as a mat footing of concrete, or as a simple floor not less than four (4) inches thick. The pit floor shall, in all cases, be smooth, with a pitch to a common point of drainage, and free from pockets in which water will stand.

2107. **Anchor Bolts:** Anchor bolts, not less than seven-eighths (⅞) inch in diameter, threaded and with nuts and washers, shall be provided in the foundations for lever stands to match the bolt holes provided for securing the stands, and they shall extend into the concrete not less than eight (8) inches.

2108. **Anchorage for Floating Levers:** A floating lever, that is, one exerting an upward pull at its fulcrum, shall be anchored to the foundation to resist not less than twice the upward pull produced at the fulcrum pivot by a capacity load on the scale.

22. Scale Beam House or Box

2201. **Scale Beam House or Box:** When the scale is not located in a building, the scale beam shall be adequately protected from the weather by being enclosed in a house or box. When a scale is located in a building, it shall, when necessary, be similarly protected from injury.

2202. **Design:** The minimum inside width of the scale house shall be four (4) feet, and the minimum length shall be sufficient to allow the installation therein of the beam shelf and beam. It shall be provided with windows of such size and location as will give the weigher, when weighing, a clear and unobstructed view of the scale platform and approaches. The windows shall be glazed with clear glass or clear wire glass. If the beam is required to be boxed, the box shall be of such size as to suitably enclose the beam shelf and beam. It shall be provided with a hinged door, or doors, of such size and in such location as to give the weigher clear and unobstructed access to the beam.

2203. **Clearance:** A clearance of not less than one (1) inch shall be provided between the inside of the scale house and the beam supports and shelf. The clearance between the edge of the platform and weighbeam pillar, beam box or scale house shall be sufficient to permit the normal functions of weighing the widest loads required to be handled.

23. Installation

2301. **Fastening of Stands:** After alining the stands, the anchor bolt holes in the castings shall be filled with cement, sulphur or other suitable material, and the anchor bolt nuts brought down tight.

2302. **Alinement:** All levers shall be level and connections plumb throughout the scale.

24. Platforms

2401. **Security Against Tipping:** All scale platforms shall be proportioned so that, for any possible application of the loads specified for different classes of scales in Section 6, no tipping can occur. (See Item 516.)

2402. **Timber:** In all scale platforms, timber shall not be used for floor beams, stringers, or in any members, except floor covering, required to take shearing or compressive stress perpendicular to the grain, or stress in transverse bending. Timber may be used for floor covering and, as required, for spiking or fastening strips for the floor covering. (See Items 514 and 2409.)

2403. **Weigh-Bridges:** For motor truck and built-in scales, weigh-bridge girders, floor beams and stringers shall be made of steel conforming to American Railway Engineering Association Specifications for Steel Highway Bridges, Sections II and III.

2404. **Sections and Strength:**

(a) Weigh-bridge members shall be designed in accordance with Sections XIV and XV of the American Railway Engineering Association Specifications for Steel Highway Bridges, except as the permissible working stresses and loading conditions are modified by Sections 5 and 6 herein.

(b) **Motor Truck Scales:** In motor truck scale weigh-bridges, the section moduli of main girders shall be shown in Table 8.

TABLE 8

SECTION MODULI OF MAIN WEIGH-BRIDGE GIRDERS FOR MOTOR TRUCK SCALES

(These values contain provision for impact)

Capacity and Platform Size		*Section Modulus, One Girder*	
		Plank or Steel Plate Deck	*Concrete Deck*
24,000 lb.	16′ by 8′	38.0	40.3
36,000 lb.	18′ by 9′	64.6	68.1
over)	(20′ by 9′	68.7	73.1
36,000 lb.)	(20′ by 10′	69.3	74.1
but less than)	(22′ by 9′	81.4	86.8
60,000 lb.)	(24′ by 9′	98.6	104.9
	(24′ by 10′	99.5	107.1
60,000 lb.)	24′ by 10′	178.4	185.7
60,000 lb.)	34′ by 10′	189.7	204.4
to 70,000 lb.)			

2405. **Bracing:**

(a) **Built-in Scales:** Weigh-bridges for built-in scales ordinarily will require no bracing other than floor beams and corner plates.

(b) **Motor Truck Scales:** If the floor beams are mounted above the main girders, weigh-bridges of motor truck scales with solid floor construction or with transverse floor beams on 36-inch centers or less will require no lateral bracing. Otherwise bracing shall be designed for the forces in Item 605—(a). The internal bracing members shall not be less than 3″ × 3″ × ¼″ angles.

(c) **Cross Frames:** Motor truck scale weigh-bridges with the floor beams mounted above the main girders shall be provided with end cross frames and at least one intermediate cross frame. If the floor beams are internally framed and the weigh-bridge otherwise adequately braced, the end and intermediate cross frames may be omitted.

2406. **Fabrication and Assembly:**

(a) **Motor Truck Scales:** The weigh-bridges for motor truck scales shall, when practicable, be assembled and riveted up complete in the shop. When field assembly is necessary, the parts shall be properly assembled in the shop and match-marked. Connecting holes shall be reamed to fit.

(b) **Built-in Scales:** The weigh-bridges for built-in scales shall be assembled and riveted, or bolted up in the shop under proper inspection. When delivered, they shall be square and the surfaces receiving the platform bearings shall be parallel.

2407. **Platform Bearings:** In motor truck scales and built-in scales, the tops of platform bearings contacting the weigh-bridge girders shall be finished to within $\frac{1}{32}$ inch of a true plane. These tops shall be provided with bolt holes of sufficiently large diameter to allow for the transverse and longitudinal adjustment necessary to secure proper alinement of parts.

2408. **Deck:** The deck or floor shall be designed so that, without exceeding the permissible stresses, it will support and distribute the capacity load and incidental forces when applied as described in Section 6, and so as to produce the maximum stress in any part of the floor.

2409. **Flooring:** The flooring shall be of such material as will resist wear, will under all weather conditions provide traction to power-driven vehicles, and which can be waterproofed. If timber is used, its quality must be at least No. 1 Common dimension, treated with a preservative.

2410. **Self-contained and Portable Scales:** The platforms of self-contained and portable scales shall be entirely of metal, or a metal frame with a hardwood center panel, and shall be so designed that, without exceeding the permissible stresses, the loads and forces prescribed in Section 6, when so applied as to produce maximum stress, can be sustained.

25. Light, Drainage and Ventilation

2501. **Light:** Proper lighting of the scale weighing beam and scale platform shall be provided.

2502. **Drainage:** Adequate drainage for scale pits shall be provided and maintained.

2503. **Ventilation:** All scale pits shall be ventilated to meet the needs of each particular case, the object being to minimize the amount of moisture in the air in the pit and so to retard rusting of scale parts and structural steel.

26. Entrance to Scale Pit

2601. **Location:** For built-in scales, the entrance to the scale pit for inspection purposes shall be through the platform of the scale, foundation wall, or the neck of the scale pit, and shall be closed by a suitable door; for motor truck scales, the entrance to the scale pit shall be through the foundation wall or neck of the pit.

27. Protection from Corrosion

2701. **Shop Painting:** When no shop inspection is provided, or after shop inspection when it is provided, all parts of the mechanism and structural steel of motor truck and built-in scales shall be given one coat of red lead and linseed oil, and all parts of the mechanism of self-contained and portable scales shall be given two coats, and the inside of the platform and the frame one coat of paint. In riveted work, surfaces coming in contact shall be given one coat of red lead paint before being riveted together. All parts of motor truck and built-in scales which are inaccessible after erection shall be given a second shop coat of red lead paint.

2702. **Field Painting:** All parts of the scale mechanism and structural steel of motor truck and built-in scales shall be cleaned and painted with one coat (and preferably two coats) of approved paint in the field before installation.

SUPPLEMENT TO REPORT OF COMMITTEE XIV—YARDS AND TERMINALS

MODIFICATIONS TO APPENDIX D, REPORT OF SUB-COMMITTEE 5, SCALES USED IN RAILWAY SERVICE (BULLETIN 361, NOVEMBER, 1933)

To the American Railway Engineering Association:

PROPOSED SPECIFICATIONS FOR THE MANUFACTURE AND INSTALLATION OF MOTOR TRUCK, BUILT-IN, SELF-CONTAINED AND PORTABLE SCALES FOR RAILWAY SERVICE (PAGE 447)

The Scale Sub-Committee was unable to complete this year the assignment of revising the Specifications for Motor Truck, Built-in, Self-Contained and Portable Scales for Railway Service now contained in the 1929 Manual, page 1034. Nevertheless, developments in the trade seem to require that the work thus far completed be introduced to an active status. For that reason we propose to withdraw this year from the Manual the subject material there, and to publish the work thus far completed as "Information." Since the conclusion to do that was reached opportunity to press the work farther was found. In order that the "Information" formally published might contain the advantage of the latest developments, we offer them herewith as a Supplemental Report with the intent they shall be published in the current Proceedings either suitably incorporated in the main report, or as an appendix to it.

The modifications apply to Appendix D, page 447, Bulletin 361, and are to be inserted at the places indicated.

Section 5—Page 449

Design Data—Working Stresses and Formulas

Change Item 501, Table 2, thus: Follow the table to the item, Cast-Iron (Semi-Steel), change to Cast Iron (Semi-Steel, and Other Alloys). See Item 502.

Stet to the end of the table.

Change Item 502, Page 450, thus:

502. **Cast Iron (Semi-Steel, and Other Alloys).**

(a) Semi-Steel: For the purposes covered by these specifications, castings, or iron containing 18 per cent or more of steel are designated as semi-steel castings. For the corresponding thickness of section and nature of stress, the working stresses for the semi-steel shall be 1.6 times those given in Table 2 for grey cast iron.

(b) Other Alloys: For other alloys intended or represented to be "high strength" cast iron, unit working stresses other than those given in Table 2 may be used, provided these are acceptable to the purchaser and have been established according to test routine followed or prescribed by the American Society for Testing Materials. In all instances, the purchaser, if he requests, shall be furnished with sufficient data to enable him to determine the physical properties of the particular "high strength" material proposed to be used.

Section 6—Page 452

Particulars of Loading

Change Item 602, Page 453, thus:

602. **Dead Load.**

(a) Unless provision is otherwise made in these specifications, the dead load shall be considered in the design of scales. The dead load shall be considered as the weight of all parts of the scale structure supported by the main lever load pivots and balanced out for the zero beam reading.

(b) The unit weights in Table 3 shall be used in computing dead load.

Continue with Table 3.

Change Table 4, Page 453, thus:

SCHEDULE OF LIVE LOADS FOR MOTOR TRUCK SCALES

(a) For scales of 24,000 lb. nominal capacity with 16 ft. by 8 ft. platform, 36,000 lb. nominal capacity with 18 ft. by 9 ft. platform, etc. Stet the rest of the table.

Change Table 5, Item 603, Page 453, thus:

TABLE 5

COMBINED LIVE AND DEAD LOADS TO BE USED IN THE DESIGN OF MOTOR TRUCK SCALES

NOTE 1—These loads are to be used for the design of parts made of materials for which the safe stresses are given in Section 5.

NOTE 2—The "corner load" is the maximum reaction at any main load pivot.

NOTE 3—The "end load" is the maximum reaction at the two main load pivots at the same end of the scale.

NOTE 4—For definition of "nominal capacity," see Item 301-(b).

Nominal Capacity (Pounds)	*Platform Size (Feet)*	*Corner Load (Pounds)*	*End Load (Pounds)*	*Total Load (Pounds)*
24,000	16 by 8	14,400	27,600	36,100
36,000	18 by 9	23,000	40,900	52,200
60,000	24 by 10	42,300	69,200	85,800

The values just given are for the special scales designed particularly for the two axled vehicle described in Table 4, under the subhead (a).

For regular service and for other conditions of loading, not more severe than those described in Table 4, under the subhead (b), the following values apply:

Less than 60,000.....	20 by 9	25,700	47,800	83,100
Same	20 by 10	27,900	48,900	84,900
Same	22 by 9	27,600	50,500	85,100
Same	24 by 9	29,100	53,800	87,100
Same	24 by 10	31,500	55,100	89,800
60,000 to 70,000.....	34 by 10	38,500	68,300	107,400

Change Item 606, Page 454, thus:

Longitudinal Forces

606. **Longitudinal Forces.**

(a) **Motor Truck and Built-in Scales:** In motor truck and built-in scales, provision shall be made for the effect of a longitudinal force of 10 per cent of the capacity of the scale acting in the plane of the platform and in a vertical plane through the longitudinal center line.

Section 7—Scale Levers

Change Item 701, Page 455, thus:

701. **Limitation of Type:** Truss rods shall not be used in parts of the lever system except to stiffen levers laterally, or to prevent whipping and vibration due to impacting loads. Truss rods designed as parts of a lever structure to support vertically applied loads will not be permitted.

Section 13—Weighbeams and Accessories

Change Item 1313, thus:

1313. **Balance Ball:** For motor truck scales the position of the balance ball shall be vertically adjustable. Unless otherwise required by law or regulation, longitudinal movement shall be controlled by means of a self-contained hand-operated screw or other device which will not require the ball to be rotated in making adjustments. Means for locking the ball in position shall be provided.

Change Section 24—**Platforms,** thus:

Stet to Table 8, then change

TABLE 8

SECTION MODULI OF MAIN WEIGHBRIDGE GIRDERS FOR MOTOR TRUCK SCALES

(These Values Contain Provision for Impact)

Nominal Capacity (Pounds)	*Platform Size (Feet)*	*Section Modulus One Girder*
SPECIAL SERIES		
24,000	16 by 8	40.3
36,000	18 by 9	68.1
60,000	24 by 10	185.7
REGULAR SERIES		
Less than 60,000	20 by 9	73.1
Same	20 by 10	74.1
Same	22 by 9	86.8
Same	24 by 9	104.9
Same	24 by 10	107.1
60,000 to 70,000	34 by 10	204.4

Stet the rest of the section.

Section 12—Checks—Page 457

Item 1201. **Type:** The weighbridges or platforms of all scales shall be equipped with devices which effectively restrict motion in any horizontal direction sufficiently to prevent contact between the platform and foundation wall or coping, so designed, as to withstand the horizontal forces prescribed in items 605 and 606. For motor truck and built-in scales, if checks either of the rod or bumper type are used, they shall be adjustable.

Respectfully submitted,

THE COMMITTEE ON YARDS AND TERMINALS,

M. J. J. HARRISON, *Chairman.*

Chicago, March 9, 1934.

Appendix E

(6) BIBLIOGRAPHY ON SUBJECTS PERTAINING TO YARDS AND TERMINALS APPEARING IN CURRENT PERIODICALS

Compiled by E. E. R. Tratman

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Appendix F

(7) THE EXPEDITING OF FREIGHT CAR MOVEMENTS THROUGH YARDS

W. F. Cummings, Chairman, Sub-Committee; J. R. W. Ambrose, J. E. Armstrong, H. M. Bassett, N. C. L. Brown, H. F. Burch, R. J. Hammond, G. F. Hand, J. V. Hanna, M. J. J. Harrison, E. M. Hastings, W. J. Hedley, W. H. Hobbs, E. T. Johnston, L. L. Lyford, C. H. Mottier, T. R. Ratcliff, W. B. Rudd, E. E. R. Tratman, H. L. Vandament and H. M. Waite.

The Committee has restricted its report this year to a generalization of the subject with the intention, if the subject is continued, of carrying its study to more specific details.

For many years the freight yard has been recognized as a major factor in delays to car movements. Much time and consideration has been given to the subject. Much stress has been given it in books, technical papers, proceedings, etc. In 1918, John F. Wallace, speaking before the Association of Commerce at Chicago, said (Vol. 20—pp. 174–175 A.R.E.A. Proceedings):

"The Terminal problem is really the big problem of our railroad transportation system, and its solution will automatically solve most of our transportation complexities.

"While the total mileage of terminal tracks may not be too much—and in certain localities may even be insufficient—the remedy lies not entirely in additional tracks and facilities, but in a correlation and readjusting of existing facilities and the operation within the terminal zone along lines that will secure the maximum of efficiency.

"Viewed from the standpoint of delays, the railway terminal becomes even a larger factor in the transportation problem. The average freight car travels about twenty-five miles a day. The average speed of a freight train between terminals is ten or fifteen miles an hour. It is, therefore, evident that the average freight car spends twelve hours in the terminal for every hour it spends between terminals.

"Since the remedy—whatever it may be—will eventually be applied by Congress, it is highly important that the general public comprehend the fundamentals of the present transportation situation and the general nature of the changes in operation and control necessary to bring about a more efficiently operated transportation system.

"These changes will necessarily be of two kinds:—First, physical changes in terminal facilities; and, Second, changes in method of operation.

"The interchange freight should receive first consideration. It frequently happens that a car of commodities consigned from a point in the West to a point in the East is handled successively by several railroads and at every place where it passes from one railroad to another it goes through a terminal, often passing through the hands of an intermediate company, occupying space in several railroad yards, congesting interchange tracks and encountering days of delay.

"The remedy for this condition is more direct routing—and a routing that will pass the car around rather than through the larger railroad terminals. ....."

In a paper written in 1919 by E. H. Lee, Vive-President of the Chicago and Western Indiana Railroad Company, and appearing on pp. 180–188—Vol. 20 of the Proceedings of this Association, there appear among other things these comments—

"It may be well to briefly review the conditions as they now exist, although such a review will contain a statement of facts which are well known to most railroad men, and are coming to be better known by the general public and which may, therefore, seem more or less trite.

"Until about ten years ago the railroads of the country expended great sums of money for double track, the reduction of grades, the extension of sidetracks, the construction of new branch lines, and other facilities for accumulating traffic and handling it more expeditiously to the terminals, without any corresponding expenditure to improve facilities in the terminals themselves. Recently more of an effort has been made to improve and enlarge terminals; but on many of the railroads the important terminal facilities in the larger cities are in great measure what they were ten years ago. Although from the nature of the case, since early in the history of the railroad industry, terminals have been the principal points of congestion, this tendency has become greatly aggravated during recent years. It is not too much to say that at this time the capacity of the larger terminals of the country are the measure of the transportation output which can be delivered by the railroads.

* * * * * *

"Of the requirements mentioned as fundamentally necessary for the efficient manufacture of transportation only one remains, viz., good methods and practices. It is just here, in the view of the writer, that important changes and improvements may be made which will quite radically improve the efficiency of the railroad as a whole, because they will reduce congestion in the terminals, this being, as already stated, the chief enemy to transportation efficiency as a whole.

"Congestion is defined as a condition of undue pressure, a state of unnatural crowding; and congestion on the railroads, like congestion in the body, is a disease which interferes with the normal functions, and is to be reduced by the use of various devices and means adapted to remove the undue pressure in the parts affected.

"Two of the principal causes of congestion in terminals, which in turn act in a vicious circle with congestion itself, each to cause the growth of the other, are dead time and the rehandling of cars. It is safe to say that any method or practice which secures the maximum reduction in dead time, and in the rehandling of cars, will also secure maximum reduction in the congestion of terminals, and, therefore, maximum increase in the efficiency of the railroads of the country as a whole.

"For the purpose of this discussion, dead time is limited to and may be defined as time spent by the train crew after an engine has been manned, in getting out of the roundhouse, pulling up to and coupling onto the train, testing the air, etc., at the outgoing end of the trip; time lost in setting out and picking up; and time spent in putting away the train with the various similar attendant operations at the incoming end. This so-called dead time thus defined is to be distinguishable from time spent in actually passing over the road. Its serious effect in terminal operations is not generally appreciated being of much less relative importance in open country operation than in terminal operation.

"This is true because dead time remains more or less constant, while running time tends to vary directly with the length of the run. As an illustration—assume an open country division 100 miles long, average freight running time over the division 8 hours; as compared with a transfer run in a terminal 12 miles long, average running time 1 hour. If the dead time is in each case two hours, the dead time loss on the country division is only 20 percent, whereas on the transfer run it is 66⅔ percent.

"This comparison may seem exaggerated, but an investigation made by the writer some years ago, which is believed to have been reasonably accurate, disclosed that in an actual case under ordinary conditions and where no undue congestion existed dead time as above defined consumed 65 percent of the total service time of all transfer trains.

"Rehandling cars is brought about by a number of different causes. Lack of proper method, as well as lack of careful and intelligent planning on the part of trainmasters, yardmasters and conductors responsible for transfer movements, is partly responsible, but these causes operate during times of normal movement as well as during times of congestion. The great cause for rehandling is undoubtedly congestion, which is in turn further aggravated by the rehandling itself.

* * * * * *

"At most minor terminals and junction points, direct deliveries are made between the railroads, and at some points the chief improvement possible is doubtless to be secured by a coordination of facilities when practicable, and an improvement in methods, as, for instance, by the reciprocal delivery of cars, thereby eliminating light running. In the case of industries served by more than one line, it has been the general practice in the past for each road to handle its own business into and out of the same, although in one case familiar to the writer all such industrial deliveries have been handled by a terminal

railroad for the tenant companies using its line for a period of over 30 years, and with results entirely satisfactory in the way of a reduction of both engine time and cost.

* * * * * *

"The three things among those suggested in this discussion which it is believed would have especial effort in controlling congestion are the construction of storage yards, outside the terminals; the advance classification of transfer cars, to the greatest practicable extent; and an extension of the authority of the men in charge of terminal operations, whatever their rank or title, in order that they may better control the flow of traffic to and through the terminal."

If these observations, comments and conclusions as to the seriousness of congestion and delays in terminals were worth while considering then, they surely are today, because, whereas delays and congestion at that time merely meant handicap to business and criticism of the railroads, today it definitely means loss of business because of the competition of the highway motor vehicles. Many equally good observations could be quoted from other eminent authorities to show the importance of terminal delays.

In view of the present conditions of competing services, the present duplication of services and facilities, general demands for quicker movements of freight to permit reduction of stock supplies, etc., the continuing loss of business to the motor transport, the desirability of maintaining a favorable attitude of the public toward the railroad by meeting reasonable demands and requirements, the insistent demands for a reduction in freight rates, etc., it is apparent to all of us that now more than ever must we give service.

We are all aware of the recent trend in transportation towards increased speed and prompt delivery of all classes of freight and the fact that results are being obtained. The reduction in time has been accomplished by greatly increased road speed and by improved operating methods in terminals. This Committee interprets its assignment to outline the proper facilities for such operation. The subject might be generally subdivided as follows:

(a)—Movement from point of origin to first departure. This includes industrial switching, transfer movements and primary classification.
(b)—Movement through intermediate yards.
- (b–1)—Major intermediate yards where trains are broken up such as at important interchange points and reclassification points.
- (b–2)—Secondary intermediate yards where through freights are main-tracked. Tonnage may be added or subtracted at these points. It may be necessary to change power and usually is necessary to change cabooses.

(c)—Movement from last terminal to destination, which is, of course, the reverse of (a).

The problem is affected among other things by—

Operating program and routine.
Yard and terminal design.
Construction and operating economies.
Loading and unloading methods of shippers and consignees.
Public body regulations.
Highway truck movements between terminals and points of origin and destination.
Co-operation at transfer points as between railroads.

The first consideration should be to study improved methods of operation, many of which are in effect on railways today. These include among others—

Improved methods of classification over the entire system, assigning particular duties to each yard and obtaining a clear idea as to what is to be done at each terminal.

The quick assembling and get away of freight trains when freight houses are closed.

The quick assembling of cars from industries and other railroads.

The advance classification of cars on one railroad for another.

The running of locomotives of one railroad through on others.

The unification and coordination in use of terminals.

The use of smaller and lighter equipment on short haul work.

The segregation of short haul work.

The use of off-rail terminals.

Use of container cars.

Use of demountable body cars or cars adjusted to rail and highway service.

This having been done, there should then be the planning of proper facilities to carry out the operating program. Some of the features that may help to speed up the movement through yards are—

Main tracking of trains.

Hump Yards.

Installation of Car Retarders.

Main track coaling stations so arranged that coal, water and sand can be taken at the same stop, particularly at intermediate yards where power is run through and trains main-tracked as much as possible.

High speed turnouts at yard entrances and other locations.

Power operated turnouts at yard entrances and other locations.

Tracks of sufficient length to accommodate trains without doubling.

Floodlights for night switching.

Hot oiling facilities.

Communication facilities, (teletype, pneumatic tubes, loud speaker, etc.)

Air lines in receiving and departure yards.

Good alinement on running tracks.

Good gradients on running tracks.

Signals on long running tracks used in both directions.

Proper spacing of tracks in receiving and departure yards to facilitate inspection and light running repairs.

Proper design at hump end of receiving yards and entrances and exits of flat yards to release road power with minimum interference.

Compact arrangement of turnouts in flat yards to minimize time necessary to throw switches and for switching.

Proper length of ladders in flat yards to avoid unnecessary engine mileage.

Proper length of classification tracks in flat yards to avoid unnecessary engine mileage.

Proper gradients for ladders and body tracks in flat yards.

Good visibility particularly on ladders and drill tracks in flat yards.

Convenient and proper location and size of—

Light repair tracks.

Icing stations.

Poultry feeding platforms, etc.

Classification yards with respect to points of interchange with other railroads and industries and freight houses, as well as number of tracks with relation to number of classifications.

Secondary classification yards.

Receiving yards in relation to classification yards.

Hold tracks.

Departure tracks.

Caboose tracks.

Engine facilities.

The question of terminal delays has been given attention by this and other committees of this Association heretofore. In Vol. 19, pp. 316 to 323, is a report on War Emergency Yard Improvements, and in Vol. 20, pp. 159 to 172 inclusive is an excellent

report on the unit operation of large terminals, including a Catechism on Unit Operations of Railroad Terminals, which this Committee recommends as being timely.

From time to time Committee XIV—Yards and Terminals, Committee XVIII—Electricity and Committee XXI—Economics of Railway Operation have reported as to good practice with respect to some of the items which this Committee has stated above may help to expedite the movement of freight cars through yards. For ready reference a tabulation of such is given herewith.

YARD FACILITIES

	A.R.E.A. References	
	Manual—1929 and Supplements	*Proceedings (Vol. and page)*
1.—Loading and unloading tracks		
(a) House, team and industry tracks		
(1) Tracks to head in same direction, if possible, to facilitate switching		
(2) Each group to be located as compactly as possible		
(3) Convenient track connections between all points where cars to be picked up or delivered	Page 1000, Par. (49)	
(4) Lead tracks for switching clear of running tracks		
2.—Receiving yard	" 998, Par. (18–22) incl.	19–318; 26–719, 723; 27–372; 29–140
(1) Close to classification yard		
(2) Facilities for quick release of road engines	" 1000, Par. (49) " 1001, Par. (62) Bull. July 1932, p. 39	26–724; 32–210; 33–114
(3) Compressed air connections for testing air brakes	Page 998, Par. (22) " 1002, Par. (64)	26–723
(4) High speed turnouts		
3.—Classification Yard	Page 998, Par. (23–27) incl. " 1421, Par. (1–5 incl.) Bull. July 1932, p. 40	19–318; 25–735; 27–372; 29–410; 32–210; 33–115
(a) Hump Yard	Page 997, Par. (5c) " 1000–1001, Par. (51–56) incl. Bull. July 1931, p. 93 " July 1932, p. 39 " June 1933, p. 57	7–130; 9–249, 514; 18–714; 27–375; 28–654; 29–453; 30–762; 31–781, 1014; 32–210, 693; 33–114, 129; 34–168, 177
(1) Car Retarders	Bull. July 1932, p. 40 " June 1933, p. 57	27–381; 28–650; 29–415; 31–781; 32–213; 33–115; 34–178
(2) Power operated switches	" July 1932, p. 40	29–415; 31–781; 32–213; 33–115

	A.R.E.A. References	
	Manual—1929 and Supplements	*Proceedings (Vol. and page)*
(3) Teletype machines	Bull. July 1932, p. 40	29–416; 32–213; 33–115
(4) Pneumatic tubes	" July 1932, p. 40	29–416; 32–213; 33–115
(5) Loud speakers	" July 1932, p. 40	32–213; 33–115
(6) Floodlighting	Page 998, Par. (13) Bull. July 1932, p. 40	9–528; 29–415; 30–451; Bull. Aug. 1930, p. 51; 31–1445; 32–213; Bull. Aug. 1931, p. 53; 32–213; 33–115; Bull. Aug. 1932, p. 57
(7) Hot oilers	Bull. July 1932, p. 41	32–213; 33–116
(8) Flange oilers	Bull. July 1932, p. 41	32–213; 33–116
(9) Track scales properly located	Page 1000, Par. (50) Bull. July 1932, p. 40	21–886; 29–417; 32–212; 33–115
(b) Flat Yard	Page 997, Par. (5a)–(5b)	27–374
(1) Compact switch groups		
(2) Short ladders		
(3) Power operated switches		
(4) Loud speakers		
(5) Floodlighting	Page 998, Par. (13)	9–528; 30–451; 31–1445; Bull. Aug. 1931, p. 53; Bull. Aug. 1932, p. 57
(6) Good visibility	Page 1000, Par. (46)	
(7) Track scales properly located	Page 1000, Par. (50)	
(c) Double end classification tracks		
(d) Car repair facilities	Page 999, Par. (38) " 1000, Par. (42) " 1002, Par. (65)	29–411
4.—Departure Yard	Page 999, Par. (32–37) incl.	19–318; 26–719; 27–372; 29–411 23–83; 29–411; 32–210;
(1) Close to or extension of classification tracks	Bull. July 1932, p. 39	33–114
(2) Long tracks	Page 999, Par. (33)	27–373
(3) Convenient engine terminal facilities	Page 997, Par. (10)–(11)	26–720, 721; 29–414
(4) Compressed air connections for air brakes	Page 999, Par. (37) " 1002, Par. (64)	29–416
5.—Intermediate Yard		19–318
(a) Major yard		
(1) Similar facilities for reclassification of trains to those at terminal yards		
(2) High speed turnouts		
(3) Properly located crossovers	Page 1000, Par. (44)–(45)	
(4) Icing facilities accessible to pull-in tracks	Page 273; Bull. July 1932, p. 39	5–174; 29–415; 32–211; 33–114

	A.R.E.A. References	
	Manual—1929 and Supplements	*Proceedings (Vol. and page)*
(5) Stock feeding and watering facilities accessible to pull-in tracks	Bull. July 1932, p. 39	29–415; 32–211; 33–114
(b) Secondary yard		
(1) Pull-in tracks convenient to yard tracks for taking tonnage on or off at rating change point		
(2) Convenient for quick changes of crews and engine power	Page 997, Par. (10)–(11)	

REPORT OF COMMITTEE XXVII—MAINTENANCE OF WAY WORK EQUIPMENT

C. R. Knowles, *Chairman;*
W. A. Batey,
M. D. Bowen,
G. E. Boyd,
Walter Constance,
W. O. Cudworth,
J. J. Davis,
J. F. Donovan,
C. R. Edwards,
William Elmer,
G. J. Ermentrout,
Robert Faries,
C. L. Fero,
R. J. Gammie,
A. I. Gauthier,*
Paul Hamilton,
R. C. Haynes,
F. S. Hewes,
F. W. Hillman,
H. I. Hoag,
L. B. Holt,
Harry Homans,
C. H. R. Howe,
G. W. Hunt,
J. S. Huntoon,
E. A. Johnson,
Jack Largent,
E. H. Mills,
R. A. Morrison,
C. H. Morse,
G. R. Westcott, *Vice-Chairman;*
E. H. Ness,
C. H. Ordas,
E. Pharand,
T. M. Pittman,
J. G. Sheldrick,
Harry Slabotsky,
H. W. Stetson,
N. M. Trapnell,
J. B. Trenholm,
J. M. Trissal,
L. J. Turner,
Fred Zavatkay,
Committee.

* Died October 17, 1933.

To the American Railway Engineering Association:

Your Committee presents herewith report on the following subjects:

(2) Standardization of parts and accessories for railway maintenance motor cars (Appendix A). It is recommended that this report be adopted for publication in the Manual as recommended practice.

(3) Adaptability of air and electric driven tools in maintenance of way work. A report on track grinders (Appendix B) is submitted as information.

(4) Types of snow-melting devices as an aid in facilitating train operation and reducing maintenance cost (Appendix C). This report is submitted as information.

(5) Use and adaptability of track type tractors in maintenance of way work (Appendix D). This report is submitted as information.

(11) Use of weed destroying equipment, including horse-drawn and power mowers operating both on and off the track (Appendix E). This report is submitted as information.

(13) Track welding equipment (a) oxy-acetylene; (b) electric arc (Appendix F). This report is submitted as information.

(15) Use and maintenance of paint spraying equipment with outline of typical organizations for various classes of work (Appendix G). Hazards of spray painting (Appendix H). This report is submitted as information.

(16) Use and maintenance of ballast cleaning machines and conditions under which each particular type may be used (Appendix I). This report is submitted as information.

Progress is reported on the following subjects:

(1) Revision of Manual.

(6) Methods of keeping data on work equipment and labor-saving devices.

(7) The selection and training of maintainers and operators of work equipment.

(8) Use of ballast discers.

(9) Organization for the use of tie-tamping machines, air and electric.

(10) Rail laying machines and auxiliary equipment.

(12) Tie adzing, scoring and boring machines.

(14) Prepare manual of instructions for care and operation of maintenance of way work equipment.

(17) Use of oil spraying machines for oiling rails and fastenings, steel structures and roadbed.

Almon I. Gauthier

It is with profound sorrow that the Committee announces the sudden passing of Almon I. Gauthier, Assistant Division Engineer, Boston & Maine Railroad, Concord, N. H., on October 17, 1933, who at the time of his death was Chairman of Sub-Committee 12—Tie Adzing, Scoring and Boring Machines.

Mr. Gauthier's contribution to the work of our Committee, together with his splendid personality, will make his loss keenly felt by every member of the Committee.

Respectfully submitted,

THE COMMITTEE ON MAINTENANCE OF WAY WORK EQUIPMENT,

C. R. KNOWLES, *Chairman.*

Appendix A

(2) STANDARDIZATION OF PARTS AND ACCESSORIES FOR RAILWAY MAINTENANCE MOTOR CARS

G. R. Westcott, Chairman, Sub-Committee; Walter Constance, G. J. Ermentrout, Paul Hamilton, R. C. Haynes, Jack Largent, E. H. Mills, C. H. Ordas, J. G. Sheldrick, N. M. Trapnell, J. M. Trissal.

Continuing the studies of previous years your Committee has had under consideration a number of items on which recommendations have not previously been made, namely loose wheels, lubrication of axle bearings and types of shut-off cocks.

Details of these features, particularly the bushings and bearings for loose wheels, were not presented because of the fact that tests were being conducted by motor car manufacturers with the use of metal bushing.

The question of type and kind of grease cup for lubrication of axle bearings has also been given a great deal of study with a view of making definite recommendation. The development of a gasoline shut-off cock that will meet all requirements of reliability and safety is another subject that has been given careful consideration by the Committee. It is expected that we will be in a position to present report with recommendation on the above-mentioned features next year.

Progress is also reported on other details of ignition systems as well as some accessories, such as axle bearing thrust collars, belt pulleys, battery boxes, coils, etc.

Appendix B

(3) ADAPTABILITY OF AIR AND ELECTRIC DRIVEN TOOLS IN MAINTENANCE OF WAY WORK

M. D. Bowen, Chairman, Sub-Committee; G. E. Boyd, W. O. Cudworth, J. J. Davis, Robert Faries, C. L. Fero, H. I. Hoag, Harry Homans, J. S. Huntoon, C. H. Morse, T. M. Pittman, L. J. Turner.

TRACK GRINDERS

Track grinders have been designed and built to provide a more satisfactory and economical means of finishing welds on rail, frogs, and crossings, as well as grinding off overflowed metal at switch points and stock rails, and in some cases on the low side of curves. There are various types of track grinding machines designed to meet the varying conditions as found on different railroads.

Owing to the lack of suitable grinding machines in the early days of gas welding the best work was obtained by the use of the flatter, and it is only recently that suitable grinders have become available. A much better surface can be obtained by grinding after welding. The different types of grinders now on the market may be divided into two general classes (a) those equipped with revolving wheels, and (b) those known as reciprocating grinders, where a group of carborundum blocks is carried in a frame or crosshead, sliding back and forth on guides. The movement is generated by a connecting rod from a crank disc on a cross shaft driven by the engine and the cutting speed is necessarily low, being not over 300 surface feet per minute. Consequently the grinding is slow, but a perfect job is done; the blocks soon take the contour of the rail heads, the finished work is true and the two rail heads are brought to an absolutely level surface.

There are two kinds of reciprocating grinders—a double sided heavy four-wheel machine equipped with a Ford power plant, and a light portable two-wheeled machine which may be easily removed from the track to permit the passage of trains. Naturally the former does the fastest work, grinding the joints first on one rail and then the next joint on the other rail of the track. The portable machine operates on one rail only.

The grinders equipped with revolving wheels are much faster, the cutting speed of wheels with bakelite or other synthetic bonds running up to 10,000 surface feet per minute. The revolving wheel machines may be divided into two classes—those using cup wheels and those using disc wheels. The former may be the free-hand type, driven by a flexible shaft, or they may be the precision type where the wheel is carried by a crosshead sliding on guides, the machine being clamped to the track.

Revolving disc wheel track grinders may be further divided into two classes. In the first class are constant speed machines which are designed to maintain a uniform r.p.m. The second class will be considered the variable speed track grinders which are provided with a range of speeds in order that a predetermined surface speed may be maintained as the wheel is worn to a smaller diameter.

As an example of the importance of the speed adjustment on track grinders, on the basis of 10,000 peripheral feet per minute at 12 inches wheel diameter, if the revolutions per minute remain constant, the wheel will lose approximately 33⅓ per cent of its efficiency when it is reduced to 8 inches.

The disc wheel grinders may be of the free-hand type, driven by a flexible shaft, the wheel and guard being mounted in a suitable holder. This device is not the most satisfactory, as it is difficult to prevent the wheel gouging in, resulting in a poor fin-

ished surface. A more satisfactory arrangement is to mount the wheel in a frame which can be raised and lowered by a hand wheel feed and moved from side to side of the rail head while the whole machine rolls back and forth along the rails over the joint being ground. This is not a precision grinder, although good work may be done rapidly. One disadvantage is the size and weight of the machine and the impossibility providing clearance for trains when placed in the intertrack space of a multiple track railroad. Another is that the machine rolls back and forth on the rail heads which are not true plane surfaces. Any irregularities in the surfaces of the rail heads will be reproduced in the ground joint. The wheels rolling on the rails may also be out of round, and care must be taken that the powdered metal and emery dust does not pile up on the rail.

Another disc wheel machine is of the precision type, in which the wheel is carried by a crosshead sliding on guides, the machine being clamped to the track.

In addition to the surface grinders, it is important to use a cross grinder for opening the slot between the rail ends at the joint. These machines are either single sided or double sided, the latter being moved along the track, slotting first one joint in one rail and then the next joint in the other rail. Some of these grinders are equipped with one thin wheel usually ⅛-in. thick and others with two wheels, one ⅛-in. thick for the tight joints and another thicker wheel for the open joints.

Present Extent of Track Grinding Machines in Use

Questionnaires were sent to 30 railroads regarding the use of track grinders. Seven railroads report having track grinding machines of various kinds, types, and sizes in use; 5 railroads reported no grinders in service; 1 railroad reports observation of track grinding machines in use by contractors. Due to the fact that most of the track grinding machines on steam railways are comparatively new, detailed information as to their general operating efficiency is not available.

On account of recent demands for track grinding machines, numerous companies have developed grinders to be used in connection with the welding repairs of the track structure. As a matter of information grinders are confined to three general groups representing the kind of power used to drive the machines, namely, gasoline, electric and air.

The term "track grinder" will apply to all types of grinders used in the maintenance of track and will be classified under the three following sub-headings:

1. Surface Grinder.—A surface grinder is designed primarily for finishing rail ends after welding. May be used for finishing frogs after welding and for grinding off side flow and irregularities on top or side of rail, frogs or switches.

2. Cross Grinder.—A cross grinder is designed primarily for removing end flow of rail to prevent chipping.

3. Side Flow Grinder.—A side flow grinder is designed primarily for removing the overflow on stock rails in frogs and switches and also for smoothing up switch points.

Relative Merits of Various Types of Track Grinders

Relative merits will be listed as to their respective importance in carrying out the work efficiently and economically:

(1) Attached chart compiled on a speed basis of 10,000 surface feet per minute shows the r.p.m. at which grinding wheels having a synthetic rosin bond should run. It will be noted that as the size of the wheel decreases the r.p.m. must increase in

C. M. St. P. & P. R. R. Co.

OPERATING CHARACTERISTICS OF SYNTHETIC ROSIN GRINDING WHEELS

R.P.M. NECESSARY TO PRODUCE A SURFACE SPEED OF 10,000 FT. PER MIN.	14"	13½"	13"	12½"	12"	11½"	11"	10½"	10"	9½"	9"	8½"	8"	7½"	7"	6½"	6"	5½"	5"	4½"	4"	3½"	3"	2½"	2"	1½"	1"	½"	0
76394																													0
38200																												5000	0
25477																											6666	3333	0
19100																										7500	5000	2500	0
15278																									8000	6000	4000	2000	0
12732																								8333	6666	5000	3333	1666	0
10913																							8571	7143	5714	4285	2857	1428	0
9549																						8750	7500	6250	5000	3750	2500	1250	0
8489																					8888	7777	6666	5555	4444	3333	2222	1111	0
7639																				9000	8000	7000	6000	5000	4000	3000	2000	1000	0
6944																			9090	8181	7272	6363	5454	4545	3636	2727	1818	909	0
6366																		9166	8333	7500	6666	5833	5000	4166	3333	2500	1666	833	0
5875																	9230	8460	7692	6923	6153	5384	4615	3845	3080	2308	1538	769	0
5457																9285	8571	7857	7143	6428	5714	5000	4285	3571	2857	2143	1428	714	0
5095															9333	8666	8000	7333	6666	6000	5333	4666	4000	3333	2666	2000	1333	666	0
4775														9375	8750	8125	7500	6875	6250	5625	5000	4375	3750	3125	2500	1875	1250	625	0
4494													9412	8822	8235	7647	7059	6471	5882	5294	4705	4117	3529	2942	2352	1764	1176	588	0
4244												9444	8888	8333	7777	7222	6666	6111	5555	5000	4444	3888	3333	2777	2222	1666	1111	555	0
4021											9473	8947	8421	7894	7368	6842	6317	5789	5263	4736	4210	3684	3158	2631	2106	1579	1053	526	0
3820										9500	9000	8500	8000	7500	7000	6500	6000	5500	5000	4500	4000	3500	3000	2500	2000	1500	1000	500	0
3639									9523	9047	8571	8095	7619	7142	6666	6190	5714	5238	4761	4285	3810	3333	2857	2381	1901	1428	952	476	0
3472								9545	9090	8636	8181	7727	7272	6818	6363	5909	5454	5000	4545	4040	3636	3131	2727	2272	1818	1363	909	454	0
3522							9565	9130	8695	8260	7826	7391	6956	6522	6087	5652	5217	4782	4347	3913	3478	3043	2608	2174	1739	1304	869	435	0
3188						9583	9167	8750	8333	7917	7500	7083	6666	6249	5833	5416	5000	4583	4167	3750	3333	2917	2500	2083	1666	1249	833	416	0
3056					9600	9200	8800	8400	8000	7600	7200	6800	6400	6000	5600	5200	4800	4400	4000	3600	3200	2800	2400	2000	1600	1200	800	400	0
2938				9615	9230	8845	8460	8080	7692	7310	6923	6538	6153	5769	5384	5000	4615	4230	3845	3460	3080	2692	2308	1922	1538	1152	769	385	0
2829			9629	9259	8888	8518	8148	7777	7407	7037	6666	6296	5926	5555	5185	4815	4444	4074	3704	3333	2963	2593	2222	1852	1482	1111	741	371	0
2728		9642	9284	8927	8570	8213	7856	7499	7142	6785	6428	6071	5714	5357	5000	4642	4285	3928	3571	3214	2857	2500	2143	1785	1428	1071	714	357	0

SURFACE SPEED FOR GIVEN WHEEL SIZE AND R.P.M.

NOTES.—The diagonal line is the 10,000 ft. per minute line, or the line of perfect performance. All operation above the line would be in excess of 10,000 ft. per minute at any of the variable speeds, while those values below the line are for a fixed or constant speed and show the exact surface speed for that given r.p.m.

The numbers also denote efficiency in per cent by inserting a decimal point before the last two digits. This efficiency is for any given r.p.m. directly to its left at the margin.

order to maintain a predetermined peripheral speed. It will be necessary to check and correct the grinding wheel speeds frequently in order to maintain a constant surface speed. Failure to maintain constant surface speed may result in losses of grinding wheel efficiency up to 75 per cent.

(2) Gasoline engines are a desirable and economical source of power in operating track grinders. These engines are equipped with mechanical governors and adjustments are provided to maintain the variable speeds required to completely wear out the grinding wheels. This wide range of speeds is not provided in any other form of power.

(3) It has been found, from observation of many different types of drives that the V-belt, wherever it can be used, provides a very efficient and trouble-proof method of driving track grinding wheels. There are some instances where metal flexible shafts, due to the peculiar nature of the work, are very desirable. They are usually used, however, in conjunction with V-belt drive assemblies.

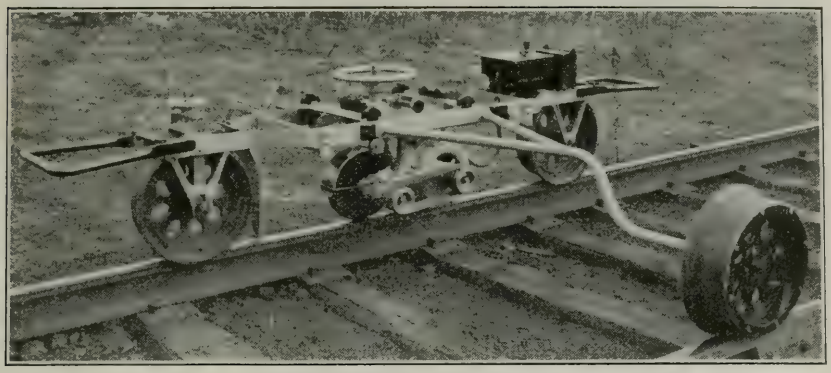
(4) Lubrication of grinding machines cannot be overstressed. Low sodium soap types of greases are well adapted when various kinds of ball and roller bearings are used at very high speeds, such as are found in the better type of grinding machines. Ball bearings must run from approximately 2500 r.p.m. to 12,000 r.p.m. which requires very thorough lubrication. The chemical analysis of the grease referred to is approximately 95 per cent steam refined cylinder stock and 2 per cent to 5 per cent sodium soap, and is used in preference to lime soap greases.

(5) Air cleaners on gasoline motors and crank case oil breathers must be protected when engines are used on grinding machines, as the engines are required to operate in a virtual bath of emery dust. There are many types of air cleaners and breather caps on the market for this purpose, but few are efficient enough to be of any value under these conditions. The oil bath principle of carburetor air cleaners has proven more efficient than any other type so far developed. This type of cleaner requires daily care if the best results are to be obtained.

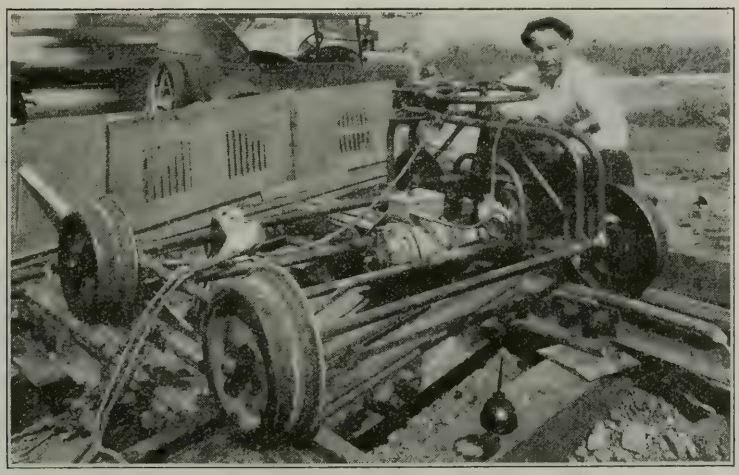
(6) Of the many methods being used of providing the vertical feed on track grinding machines, few are positive and fast enough to insure good workmanship in surface grinding when the grinding is being done on a production basis. It is essential that the feed be positive in its downward movement of the wheel, and at the same time be so designed that it will release instantly when the feed wheel is turned in the opposite direction. Machines have been developed where this feature was not considered, and there was slack in the feed mechanism that had to be removed before the adjustment would start to raise the wheel, which resulted in grinding holes beyond the end of the weld. This is not desirable, and creates a condition in ground rail ends that can only be detected for many months after completion of work.

(7) It is often considered necessary to apply excessive pressure to grinding wheels in order to maintain a rapid rate of cutting. It is more important to use light wheel pressures but maintain high peripheral speeds than it is to try to attempt to crowd a grinding wheel by creating excessive pressure.

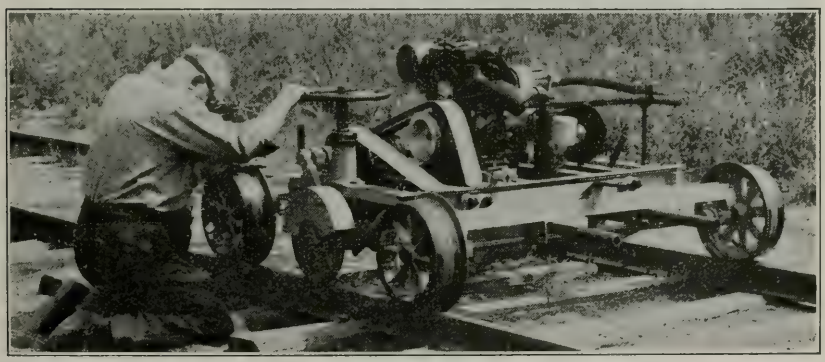
Numerous changes and improvements on track grinders are now under way and further reports will be made to bring out the latest developments.



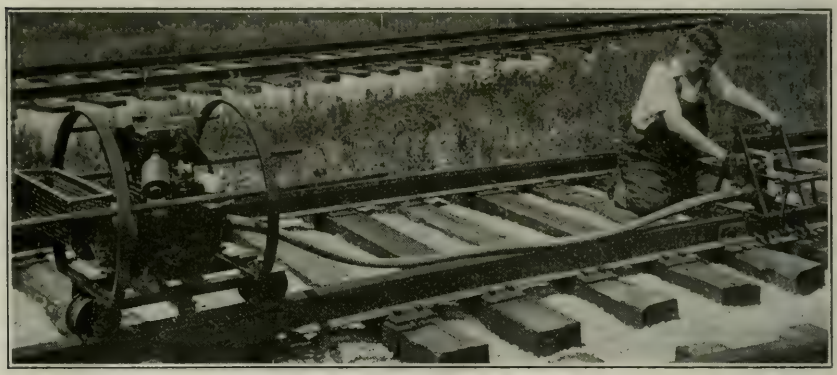
Electric Driven Surface Grinder.



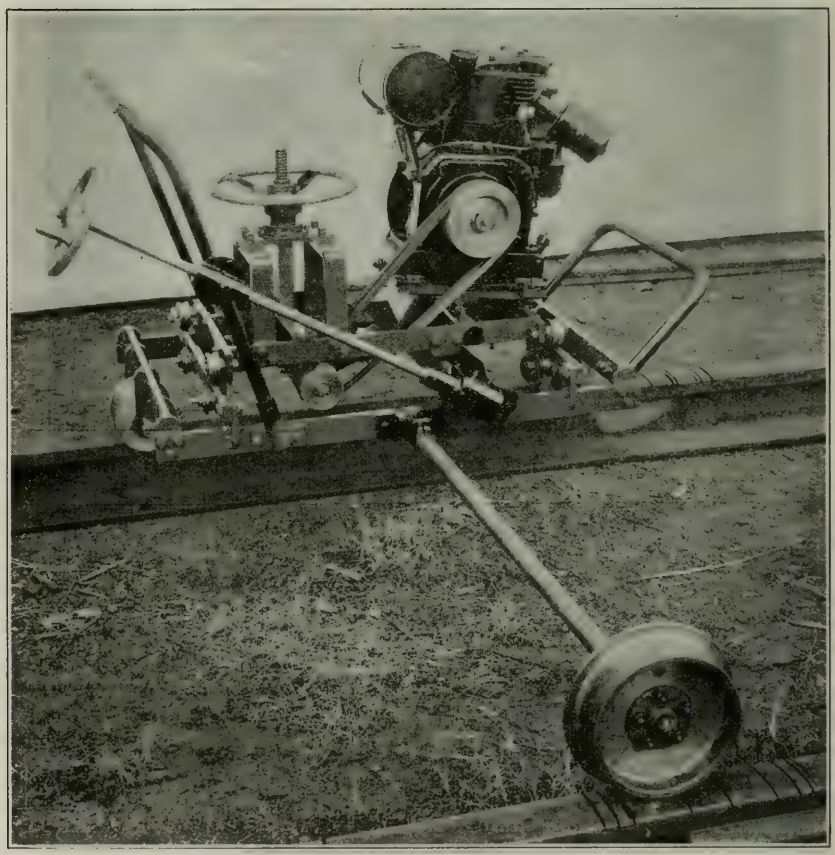
Electric Driven Cross Grinder.



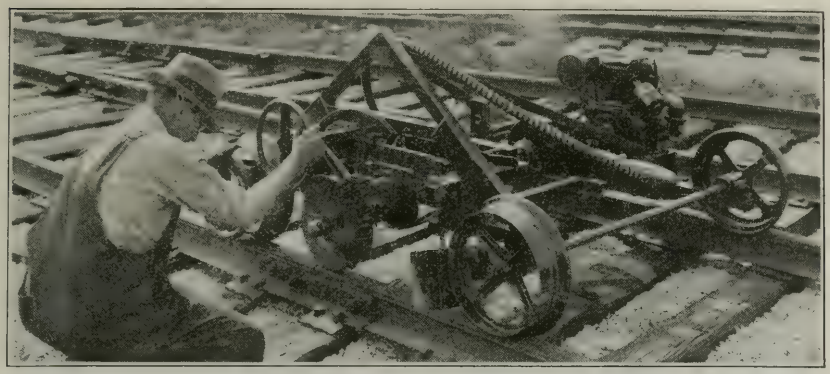
Gasoline Driven Combined Surface and Cross Grinder.



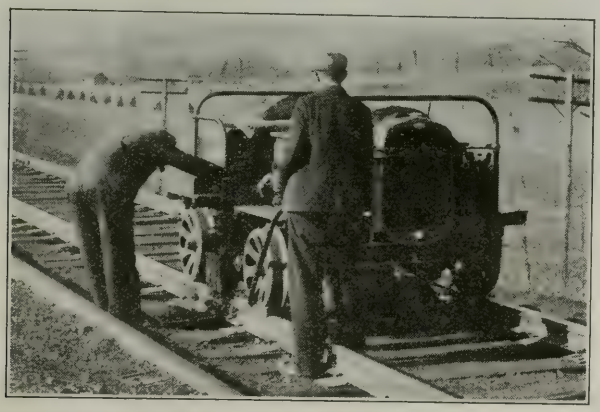
Gasoline Driven Precision Cross Grinder.



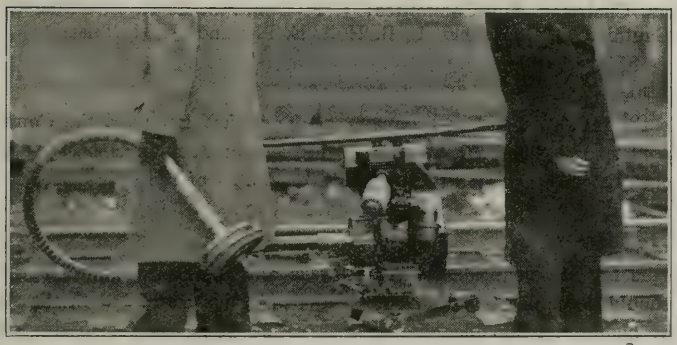
Gasoline Driven Stock Rail and Surface Grinder.



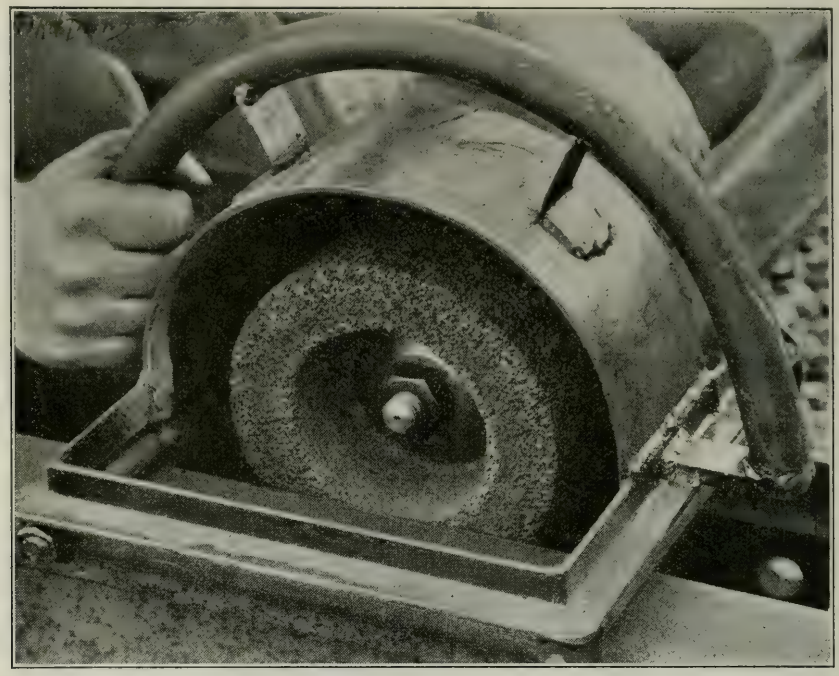
Gasoline Driven Combined Surface and Cross Grinder.



Reciprocating Surface Grinder.



Free-Hand Cup Wheel Surface Grinder, Also Adapted for Free-Hand Cross Grinding.



Close-Up of Cup Wheel Stock Rail and Switch Point Grinder.

Appendix C

(4) TYPES OF SNOW-MELTING DEVICES AS AN AID IN FACILITATING TRAIN OPERATION AND REDUCING MAINTENANCE COST

F. S. Hewes, Chairman, Sub-Committee; J. F. Donovan, C. R. Edwards, C. L. Fero, A. I. Gauthier, R. C. Haynes, L. B. Holt, E. Pharand, J. M. Trissal.

Introduction

Due to the rather exhaustive treatment of the subject last year, the Committee has found very little data this year. The following is submitted on changes and additions to its previous report (pages 358 to 383 inclusive, Vol. 34 of the Proceedings).

General Discussion

While the fire hazard incident to the storage of oils was mentioned in the previous report, it should be emphasized that rules and regulations pertaining to the storage and handling of highly inflammable oils, such as casing head gasoline, hydro carbon and snow-melting oils, should be rigidly adhered to.

Types

CHEMICALS.—2a. Calcium carbide is sometimes sprinkled on the snow around switches, frogs and guard rails, and the acetylene gas which is generated is ignited to melt the snow.

HEATERS.—9e. Hot-TraC: There are two designs of this oil burning pot. Both are made of cast iron, and each has a rather long and narrow wick which is parallel to the rail. One design (Fig. 25) is placed under the rail, but instead of resting on the ballast as is usually the case, it is suspended by a wire bracket or sling which also serves as a stop to hold the box in such a position that the wick falls just a little inside of the center of the rail base.

The other design (Fig. 26) is placed on top of the rail base where it is held in place by a wire bracket, the wick being alongside of the web of the rail.

11. Concrete snow-melting pits are now made deeper than shown in Fig. 8 of last year's report, and the drain is raised to permit the accumulation of a layer of hot water at the bottom of the pit, so snow is shoveled into the boiling water.

Barrels heated with a steam hose are also used to melt snow shoveled into them.

17a. Elec-TraC: The housing for this melter is now made of cast iron instead of pressed copper bearing steel as heretofore, otherwise it is essentially as described last year.

17g. Nu-TraC: An electric melter with a heating coil similar to that used in the Elec-TraC. The coil is housed in a cast iron box which is held in contact with the bottom of rail base by a wire clip. (Fig. 27)

Manufacturers or Distributors

"Q & C"	The Q and C Company, 90 West Street, New York, N. Y.
	The General Electric Company, Schenectady, N. Y.
"Hot-TraC"	The Rails Company,
"Elec-TraC"	Chrysler Building,
"Nu-TraC"	New York, N. Y.

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December 10, 1932.
Damage to concrete pavements caused by salt and calcium chloride.

1933 35. Proceedings American Railway Association, Electrical Section, Volume 4, 1933, page 43.
Report on electric snow-melters.

36. Proceedings, American Railway Engineering Association, Volume 35, page 370, Roadway Committee.
Methods of protecting against drifting snow and opening snow blockades.

37. Railway Engineering and Maintenance, Volume 29, pages 490–496, October, 1933. Roadmasters and Maintenance of Way Association's report on methods of handling snow and ice on railroads, including drainage of switches and other track structures where snow-melting devices are used.

Conclusion

Under proper conditions, snow-melting devices are an aid in facilitating train operation and reducing maintenance expense. There are many types available. The best type and design for the purpose is worthy of study.

A

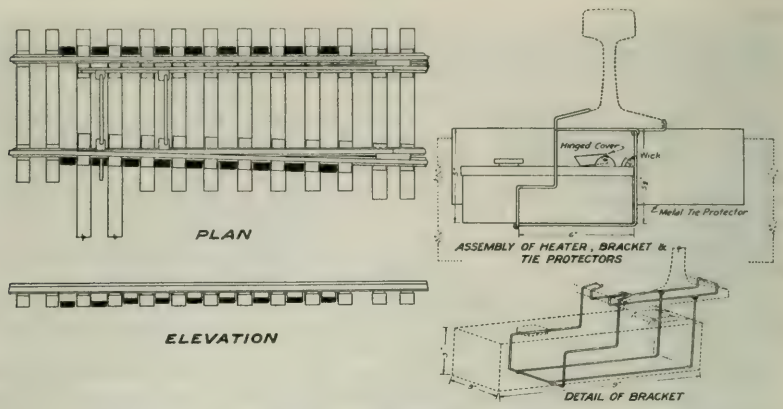


Fig. 25.—Hot-Trac Snow Melter.

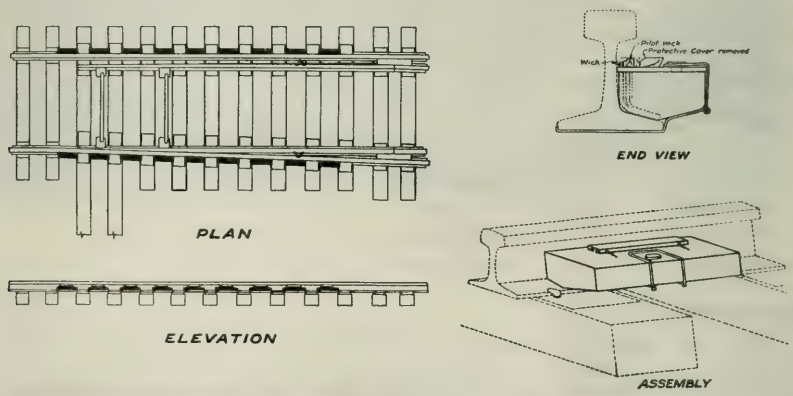


Fig. 26.—Hot-Trac Snow Melter.

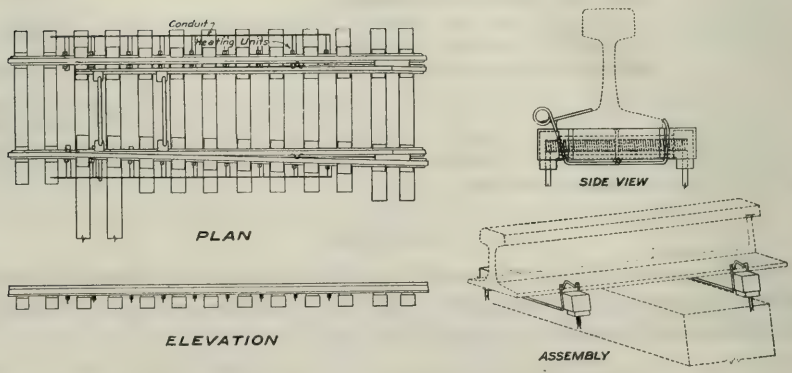


Fig. 27.—Nu-Trac Contact Electric Snow Melter.

Appendix D

(5) USE AND ADAPTABILITY OF TRACK TYPE TRACTORS IN MAINTENANCE OF WAY WORK

T. M. Pittman, Chairman, Sub-Committee; G. E. Boyd, W. O. Cudworth, G. J. Ermentrout, J. S. Huntoon, R. A. Morrison, H. W. Stetson, J. B. Trenholm, G. R. Westcott.

Supplementing our report at the last convention, which dealt with the general description and adaptability of track type tractors, your Committee desires this year to present a report on some specific operations of such tractors used in conjunction with certain specially designed attachments which adapt the machine to various uses, and to offer a method by which the qualities and merits of tractors offered by the various manufacturers may be compared more intelligently and systematically, thereby arriving at a selection of such a machine on the basis of its total score on a number of points rather than on a few emphasized by the manufacturer.

For convenience, the report will be divided into two parts; Part I dealing with the attachments and Part II presenting the scoring sheet.

Part I

FRONT END LOADER

One of the most striking examples of the versatility of track type tractors and their adaptability for maintenance of way work through the use of various attachments is afforded by relatively recent experiences with an attachment generally known as the front end loader.

The operation of this attachment is shown by the accompanying photographs. The attachment is entirely independent of the tractor, but is designed to fit the sizes of tractors best suited for railroad work and requires about 16 man hours for attaching to the standard tractor. This loader consists of a bucket, or scoop, attached to the front end of the tractor, is designed mechanically so that the scoop may be loaded by the power of the tractor as it travels forward. By means of different heights of mast or boom this scoop can be raised high enough to dump over the side of a gondola car, approximately 8½ feet; by using additional sections in the hoisting boom the lift of the scoop can be increased. The boom may be folded for convenience in loading into cars or for entry into buildings with low doors without having to remove the extra sections of the boom. The scoops are available in a number of sizes to fit the material being handled, ranging from ⅓ cu. yd. to 1 cu. yd., the smaller sizes being used for heavy material, such as wet dirt and gravel and the larger sizes for lighter material, such as cinders or snow or for cleaning litter from stock pens. The size best adapted for general use holds ¾ cu. yd.

Various means of operating the scoop are employed, but in practically all cases the scoop can be handled by the operator of the machine. In some designs the scoops are controlled by a means of cables actuated by a mechanical hoist attached to the rear of the tractor. Others are operated by an hydraulic cylinder, the oil pressure being obtained from an hydraulic pump mounted on the rear of the tractor and driven by the tractor engine.

Another design of front end loader has the bucket attached to two side rods which run along the sides of the tractor and are hinged to a post fastened to the rear end of the tractor. The bucket is raised and lowered in a vertical arc with a radius the length

of the side rods. In this type the mounting on the rear will serve as a counterbalance. Some designs permit of every operation being controlled with one lever, which raises, lowers, holds and discharges the load, as well as flaps the bucket to dislodge sticky material.

A tractor equipped with this attachment will perform practically any operation as well as the ordinary power shovel of comparable bucket capacity and boom length and is even more versatile when used as a tractor to haul wagons, or equipped with a bulldozer for spreading material after it has been deposited.

For light material the scoop can be used as a bulldozer and the material piled in windrows for more convenient loading, or the scoop can be removed and a hood and sheaves attached so the machine can be utilized as a derrick capable of handling loads of a ton or more.

For more extensive bulldozing operations the scoop can be removed and a bulldozer blade attached. This change can be made in about ten minutes without disturbing the loader attachment. The bulldozer can be set square across the front of the tractor or at an angle for side casting. It can be adjusted to cut 11 inches below the treads of the tractor or can be raised to operate at any height desired consistent with the height of boom being used. This auxiliary device is especially useful in spreading material removed from ditches and in snow removal.

The outfit is adapted to many classes of work and the method of operation is simple and obvious. The scoop can be set for digging at any elevation from 6 inches below the tractor treads to 6 feet above and can be worked in any intermediate position. In ditching, the scoop is set to the desired height and the tractor is then moved forward, usually in low gear, to secure the most power, and the scoop driven into the material. When the scoop is full it is raised to the carrying position on the boom and the tractor is operated in a high speed to the dumping point. The ability of the tractor to move forward or backward and to turn in a very small space is particularly valuable in this operation. The material can be dumped into wagons or cars, or it may be deposited over the edge of an embankment or on a fill where it is desired to raise the grade. The ¾ yard scoop is as wide as the tractor and a distinct advantage in ditching with this outfit is that the tractor travels behind the scoop on the smooth ground of the finished ditch, which facilitates the holding of a uniform grade through the ditch by maintaining the scoop at the proper elevation, whereas when a scoop is operated behind the tractor it is necessary for the tractor to operate over uneven ground, which makes it difficult to keep the bottom of the finished ditch at a uniform grade.

The same general method is followed for loading material from piles or for digging into the face of an embankment and it will be noted that the hoisting boom is so designed that while the scoop is in the loading position the edge is pointed downward, whereas when lifted to the carrying position the scoop assumes a pronounced back tilt, which prevents spillage of the material during transportation. Some scoops may be provided with a nose guard to assist in handling loose material, such as washed gravel, etc., which have a very flat angle of repose.

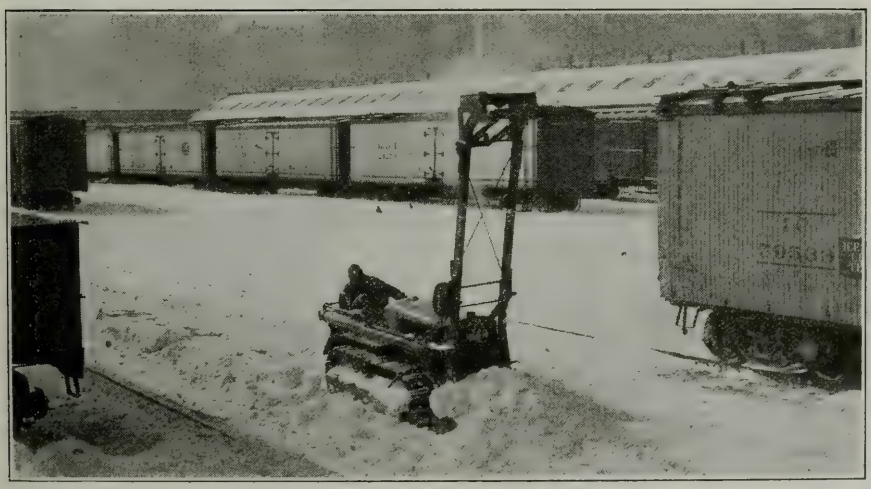
The attachment has been designed to maintain, as far as possible, the poise of the machine and counterbalances and/or safety valves have been provided in some cases to limit the power which may be applied in raising the scoop, thereby preventing the overbalancing of the machine in case a tree root or other obstacle is encountered. These safety devices can be adjusted to suit local conditions.

Some of the accompanying photographs show a front end loader being used to excellent advantage handling snow in a large railroad terminal in Chicago in February, 1933.

The snow fell to a depth of 13 inches and was followed by a drop in temperature to 20 degrees below zero. The streets and driveways leading to the freight warehouses and mail and baggage rooms were blocked by heavy drifts and many tracks were likewise blocked. A track type tractor equipped with side casting bulldozer was driven down the streets and driveways and the snow piled into windrows. The bulldozer was then replaced with a scoop and material loaded into dump wagons and gondola cars. After loading the wagons, the tractor towed them to a dumping ground. Only one man was used per machine and no difficulties were experienced on account of the extremely low temperature nor in driving the tractors over curbs and tracks or heavily drifted snow.

No reliable data on the cost of this operation are available, but the officers in charge report that four tractors placed at different yards and warehouses opened up the driveways to permit practically uninterrupted service. In former years this task had required the services of several hundred men, with less satisfactory results. These tractors are used on various maintenance of way work during the summer, but in the late fall they are moved to Chicago, where they are inspected, necessary repairs made and held in readiness for a snowstorm.

The use of track type tractors equipped with front end loaders and bulldozers offers possibilities for efficient and economical snow handling, economy being especially apparent when the use of the equipment on other work during the summer is considered. Various methods of operation will be suggested by local conditions but in general the snow is plowed from the driveways and tracks into piles of windrows. In other cases it can be plowed into catchbasins or melting pits. For quick opening up of freight houses, lanes can be plowed adjacent to the house or the snow can be piled in the spaces between the doors, leaving lanes the width of the doors leading from the doors to the main driveway.

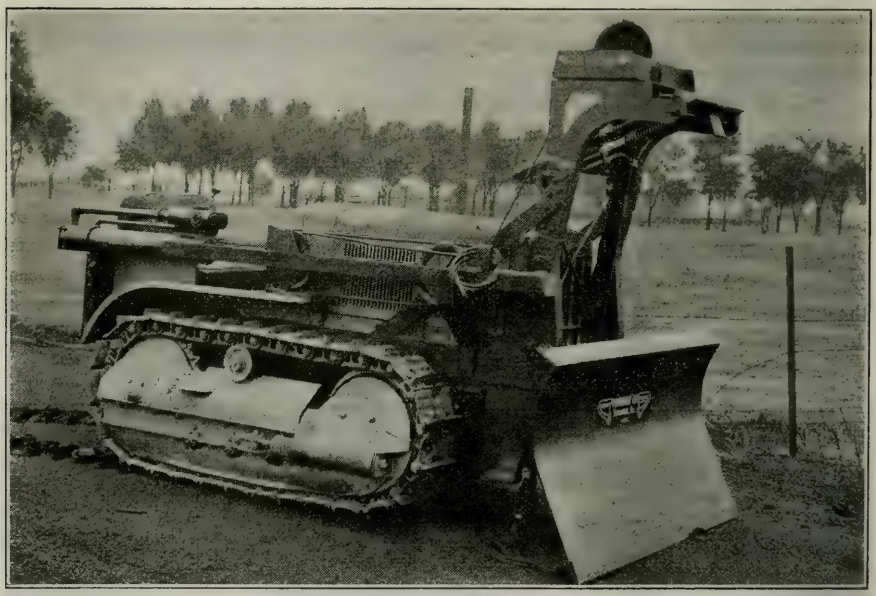


Front End Loader—Using Bucket as a Bull Dozer to Pile up Snow for Loading.

The cost of operating a machine of this type on one ditching job was as follows:

Gasoline, 2½ gal. @	30¢
Oil and grease	7¢
Operator	50¢
Total operating cost per hour	87¢

The machine moved 12 yards of dirt per hour, with an average one-way haul of 150 feet, giving a cost of 7.2 cents per cu. yd. Including depreciation and repairs, the cost would be about 14 cents per yard. This work involved removing dirt that had slid in from a cut 25 feet deep, completely filling the side ditches and reaching almost to the ties, and it was performed without slow orders or interruption of traffic. Several small trees had to be removed and small pools of water made the clay sticky and difficult to handle.



Front End Loader Scoop Replaced with Bull Dozer.

AIR COMPRESSORS

Air compressors mounted on track type tractors find a wide range of usefulness in maintenance of way work. There are a number of models available which can be readily attached to tractors of the size generally used in maintenance of way work without interferring with any of the other functions of the tractor nor affecting its stability against overturning. Power for operating the compressor is taken from the engine of the tractor.

Compressors are available in rated capacities ranging from 140 to 320 c.f.m. piston displacement and pressures of 90 lb. to 100 lb. at a speed of about 750 r.p.m. Greater capacity may be obtained by mounting two compressor units on the same tractor, which can be done with the larger sizes of tractors.

Front End Loader—Loading Snow into a Gondola Car.

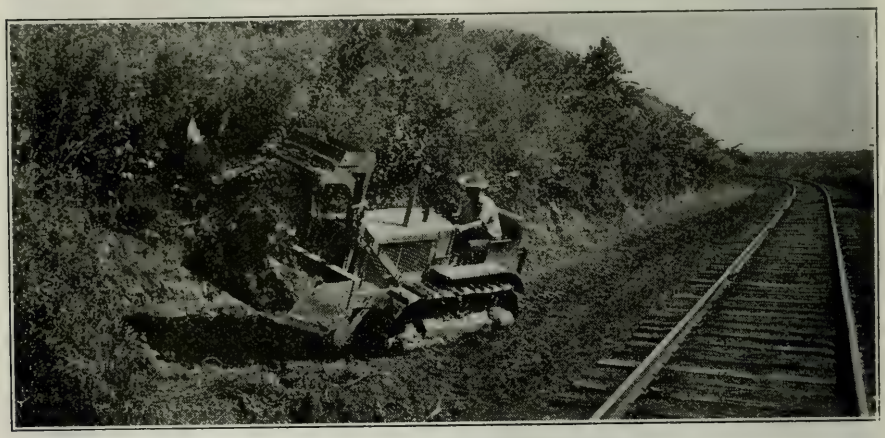
Front End Loader Hinged Type—Loading.

Front End Loader Hinged Type—Dumping

The machine can be used for any of the jobs for which compressed air is adapted, such as spray painting; tamping ties; breaking up concrete and pavement; rock drilling; driving rivets; nut running; sand blasting; cement gun work; operating small cutting, boring, drilling, grinding and hammer tools; operating air lifts and jacks; charging train lines, etc. The smaller sizes will operate either

1 rock drill (heavy duty)
4 clay diggers
2 sheeting drivers
4 riveting hammers
5 wire brushing machines—light duty
2 wire brushing machines—heavy duty
2 paving breakers
4 backfill or tie tampers
4 caulking hammers
2 concrete surface grinders

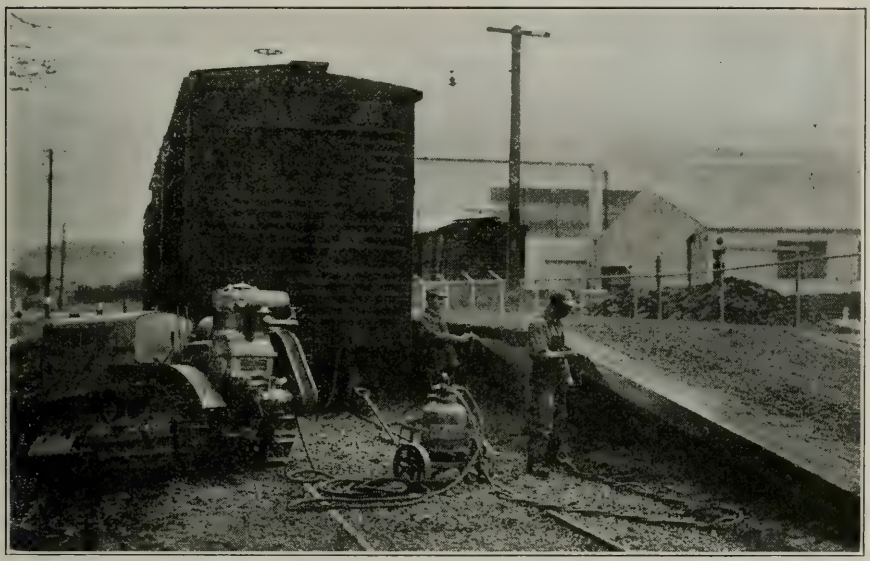
or other tools in proportion.



Front End Loader Cleaning Out a Side Ditch.

Air Compressor Mounted on Track Type Tractor. Framing Bridge Timbers.

The outfit has the advantage of easy and ready mobility which reduces the length of hose or pipe required, enables the machine to be placed on the windward side of dusty operations, such as concrete breaking or sand blasting, and permits it to be moved quickly from one job to another without having to stop the compressor. At the same time, the attachment does not interfere with the tractor's towing ability which can be used to good advantage on many jobs.



Air Compressor Mounted on a Track Type Tractor Operating a Spray Painting Outfit. "Caterpillar" Twenty Equipped with Davey Air Compressor Running Paint Spraying Machine.

Air Compressor Mounted on a Track Type Tractor Operating Tie Tampers.

On one road a model 25 track type tractor, equipped with a 140 cu. ft. capacity compressor, operated four tie tampers with 4½ inch tamping faces, working a 3 inch raise in pit run gravel. The cost per hour was as follows:

Gasoline—2.8 gal. @ 0.10	$0.28
Oil and grease	0.07
Operator	0.76
Total operating cost	$1.11

On another job of constructing a water station and moving a steel water tank, a similar outfit was used with an operating cost of $1.04 per hour. Other roads report satisfactory results from the use of similar units.

Part II

SCORING SHEET FOR TRACK TYPE TRACTORS

This scoring sheet is presented in the hope that it will provide a basis or outline for the logical and systematic comparison of tractors of various makes and aid the engineer in the selection of a particular machine for purchase.

An effort has been made to include all features which will influence such a selection and to assign to each of these features a value which will represent 100 per cent fulfillment of that feature. Additional items may suggest themselves on certain roads and different engineers may wish to vary the values given to conform to their individual experience or their special conditions and problems. A discussion of the items and their values would lead to endless opinions and the Committee, therefore, offers the scoring sheet rather as an outline which can be used for preparing a sheet to meet special conditions.

The method of using the sheet is simple. A separate sheet is made for every tractor under consideration and on that sheet the tractor is given a rating on each item, the value originally assigned to the item being considered 100 per cent. When the rating has been completed the sheet is added and the tractor receiving the highest total score should be selected.

I.	Past Experience	274
	A. Your own experience with tractors of the same make	179
	B. Experience of others with same make of tractor	75
	C. Efficiency of repair part service	20
II.	Mechanical Fitness of Tractor	380
	A. Mechanical details of tractor	190
	B. Materials used in tractor	60
	C. Ability of tractors to perform different kinds of work	90
	D. Repair parts	40
III.	Availability of Special Equipment	146
	A. Supplied by Auxiliary Manufacturing concerns	95
	B. Supplied by Tractor Manufacturer	51
IV.	First Cost	40
	A. First cost of equipment	40
V.	Distributors, Dealers or Agents	55
	A. Location of and service rendered by local dealers	25
	B. Dealer Contact	30
VI.	Manufacturer	105
	A. Stability of Manufacturer	60
	B. Capacity of plant and ability to make prompt deliveries	45
		1000

Date .....

SCORING SHEET FOR TRACK TYPE TRACTORS

Committee:—

.....

MAKE OF TRACTOR ....

MANUFACTURED BY ....

Possible Scoring Points 1000 .....

Total Assigned Points Scored ....

Factors to be Considered and Weighed	*Maximum Possible Points*		*Assigned Points*	
		Total		*Total*
I. PAST EXPERIENCE				
A. Your own past experience with tractors of the same make.				
1. Infrequency of delays due to breakdowns	22			
2. Ability of tractors to do jobs under all conditions	22			
3. Opinion of the tractor operator as to its performance	22			
4. Opinion of the foreman or others as to its general usefulness	22			
5. Length of life	22			
6. Operating costs per hour of use	22			
7. Flat or fixed costs per hour of use	22			
8. Per cent of this make tractor to all track type tractors in use on your railroad	25	179		
B. Experience of others with same make of tractors.				
1. Opinion of other owners regarding suitability of tractors for various operations	20			
2. Cost comparisons or operating data collected by other owners of same make of tractors	15			
3. Percentage of this make tractor in relation to total number of tractors in service on all railroads	40	75		

Factors to be Considered and Weighed	Maximum Possible Points		Assigned Points	
		Total		Total
C. Efficiency of repair parts service				
1. Completeness and promptness of parts service rendered	20	20		
II. Mechanical Fitness of Tractor				
A. Mechanical details of tractors.				
1. Ability to work in restricted areas; to turn short—to work in mud and snow—to work where no roads exist—to work in most severe conditions encountered on various jobs	30			
2. Protection of working parts from dirt and moisture	15			
3. Ease of operation	10			
4. Accessibility of working parts for ease of repair and lubrication	25			
5. Comfort of operator, insuring maximum output from tractor	10			
6. Adequate ground clearance	10			
7. Provision against tilting of either end under heavy loads	10			
8. Resistance against side overturning as reflected by critical tilting angle	10			
9. Facilities for attaching auxiliary equipment	20			
10. Rugged, heavy duty engine	20			
11. Efficiency of lubricating system				
a—Engine	15			
b—Chassis	15	190		
B. Materials used in Tractor.				
1. Tests made by manufacturer for quality	20			
2. Kinds of material used for parts	15			
3. Per cent of heat-treated parts by weight in tractor	15			
4. Care in machining parts to obtain perfect fit	10	60		

Factors to be Considered and Weighed	Maximum Possible Points		Assigned Points	
		Total		Total
C. Ability of tractors to perform different kinds of work				
1. Range of tractive effort	15			
2. Range of speed	15			
3. Number of models	10			
4. Adaptability of Tractor for				
a—Maintenance-of-way work	30			
b—Mechanical department work	10			
c—Telephone and telegraph work	5			
d—Purchases and stores department work	5	90		
D. Repair parts				
1. Accurate fit of repair parts	20			
2. Price of repair parts	20	40		
III. Availability of Special Equipment				
A. Supplied by Auxiliary Manufacturing Concerns (to enable more and better use of tractors).				
1. Hoisting winches	6			
2. Full revolving booms	6			
3. Side booms	6			
4. Compressors	6			
5. Clamshell booms	6			
6. Graders	5			
7. Electric welders	6			
8. Backfillers	5			
9. Bulldozers	4			
10. Scrapers	4			
11. Ditchers	5			
12. Loaders	5			
13. Boring (earth) machines	4			
14. Water pumps—attached to tractor	4			

Factors to be Considered and Weighed	Maximum Possible Points		Assigned Points	
		Total		Total
15. Rock crushers	2			
16. Drag lines	3			
17. Street sweepers	2			
18. Plows	2			
19. Snow plows	2			
20. Moving machines	2			
21. Buckets—front end	10	95		
B. Supplied by Tractor Company (to better adapt tractors for special conditions of operation).				
1. Gas or Diesel engines	4			
2. Spark arresters	4			
3. Bumper and shield	4			
4. Crankcase guard	4			
5. Cab	4			
6. Front pull hooks	4			
7. Lights	4			
8. Alcohol fuel system	3			
9. Kerosene fuel system	3			
10. Self starters	2			
11. Radiator curtains	2			
12. Mufflers	2			
13. Odometers	1			
14. Power take-offs—front—rear	2			
15. Pumps—hydraulic hoists	1			
16. Speedometers	1			
17. Belt pulley drives	1			
18. Fuel tanks—extra large	1			

Factors to be Considered and Weighed	Maximum Possible Points	Total	Assigned Points	Total
19. Vacuum fuel tanks	1			
20. Tops—Canopy—Folding	1			
21. Shoes, various	1			
22. Grousers, various		51		
IV. First Cost				
A. First cost of equipment.				
1. Price Note—Comparisons should be made on the basis of definite, known prices.	30			
2. Cost per unit of tractive power—draw bar pull times speed in miles per hour	10	40		
V. Distributors, Dealers or Agents				
A. Location of and service rendered by local dealers.				
1. Number of dealers located at points on our Railroad System	10			
2. Adequate parts service	15	25		
B. Dealer Contact				
1. Promptness—thoroughness—courtesy fairness	10			
2. Willing to cooperate—making deliveries—backing up guarantees—training operators	10			
3. Average dollar value parts stock carried by each dealer in the territory of this railroad	10	30		
VI. Manufacturer				
A. Stability of manufacturer.				
1. Number of years manufacturer has built tractors	20			
2. Current financial condition	20			
3. Financial condition for five previous years	20	60		

Factors to be Considered and Weighed	Maximum Possible Points		Assigned Points	
		Total		Total
B. Capacity of plant and ability to make prompt deliveries.				
1. Capacity of plant—complete tractors per year	15			
2. Stock of finished tractors carried on hand	15			
3. Per cent of tractor manufactured in plant	15	45		
Total Scoring Points	------	1000		

Appendix E

(11) USE OF WEED DESTROYING EQUIPMENT, INCLUDING HORSE-DRAWN AND POWER MOWERS OPERATING BOTH ON AND OFF THE TRACK

Fred Zavatkay, Chairman, Sub-Committee; J. J. Davis, R. J. Gammie, R. C. Haynes, G. W. Hunt, E. A. Johnson, Jack Largent, T. M. Pittman, J. G. Sheldrick, Harry Slabotsky, J. B. Trenholm.

Vegetation growing on the right-of-way of the railroad is objectionable for several reasons. It increases maintenance expenses, spreads fires, obstructs view, and frequently interferes with communication lines and sometimes causes delays to train movement.

The removal and prevention of vegetation growing on the roadbed reduces maintenance expenses and affords better drainage for ballast, prolongs the life of ties, eliminates slipping of locomotives on account of crushed vegetation on rails.

"Manual of Weeds," by G. A. Eljiva, MacMillan 14–18393, with description of all of the most pernicious and troublesome plants in the United States and Canada, their habits of growth and distribution, accounts for 2263 different species including a list of 64 plants that are distinctly poisonous or otherwise harmful to animal life.

Many of these weeds can be found on the right-of-way. The most troublesome are Bermuda grass, Johnson grass, crab grass, sage, horsetail, bindweed and sweet clover.

Destroying Weeds by Hand Method

The average cost of a single removal of weeds from roadbed by hand varies widely and in some localities may be as high as $125.00 per mile.

On some railroads, cutting the right-of-way once a year has been found sufficient usually to keep it in fair condition, but on others particularly in the South, weeds grow so rapidly that it is necessary to remove them twice a year. The first cutting is done late in the spring, and the second early in the fall. On account of the effectiveness being only temporary, it is necessary to repeat the performance year after year.

Concentrated effort has been directed toward the development of equipment to perform this work satisfactorily and more economically. Methods employed to a large extent have been with the use of horse-drawn plows or mowing machines and men with scythes, as well as with shovels for grassing between ties.

Various Devices Used

Many devices have been tried on railroads with view to eliminating hand weeding. The use of chemicals to kill weeds has been effectively carried out, depending on the density and character of vegetation and varying considerably as to the cost per mile. Superheated steam, revolving wire brushes, track mowing machines, discers and weed burners have been employed with various measures of effectiveness and efficiency.

Chemical Weed Killer

Experience with the use of chemical weed killer, over a period of approximately fourteen years, would indicate that the treatment has a sterilizing effect on the ballast, although the effect is cumulative only to a certain point.

The chemicals are effective in retarding and preventing the growth of biennials and perennials to a certain extent, but from experiences they have little effect on hardy perennials such as Johnson and Bermuda grass, especially in the South.

The application of chemicals is usually confined to the ballast section or roadbed and little effort is made to kill the growth outside these limits.

A typical chemical weed killer train usually consists of, from head to rear, in order listed:

1 flat car, half house and half shed, to which sprinklers are attached and on which are all the control valves and meter;

One or more steel tank cars fitted with special piping to distribute chemical to the spray car;

1 converted coach used as living car for a crew of three men. One part of coach partitioned off for air compressor;

1 locomotive and 1 caboose.

Each of the tank cars is filled with chemical and water in the required proportion and kept agitated with air. The outfit is pushed forward, thereby giving the operators clear view of the track to be sprayed. Approximately the same arrangement can be used when applying oil for killing weeds.

Non-Poisonous Powder *(Atlacide)*

This chemical has given very satisfactory results. It is applied by hand and is particularly valuable to signal departments in sprinkling around signal poles and other signal apparatus. It is also useful in destroying the Canadian thistle.

The material is furnished in 50-lb. drums with a number of 3½ lb. tin containers with perforated covers for sprinkling the material over the spots to be treated. A knapsack hand-operated duster or sprayer is also used for applying the powder over weed areas of moderate size. The knapsack duster weighs 16 lb. when empty and has a capacity for 25 lb. of powder. It can be used by one man and is useful in isolated patches of weeds or over very large areas.

If the powder becomes caked after absorbing moisture when a drum has been opened, thus preventing proper dusting, the material may be dissolved in water and applied with a whitewash spraying outfit or sprinkling can.

Steam Weed Destroyer

This method produces good results, serving the purpose of cleaning by hand and at much lower cost. The steam treatment withers the top of the vegetation, but does not kill the roots.

Mowing Machines

Track mowing machines, self-propelled and non-self-propelled are used extensively with satisfactory results, considering the limitations of such machines. They are used to cut the swath, usually 7 feet to 11 feet beyond end of ties. Where the obstructions are not numerous, these machines can be used to best advantage. Horse-drawn and tractor-drawn mowers are used around station grounds and other portions of right-of-way.

Ballast Discers

Ballast discers give best results when the track is fully ballasted with small gravel, burnt gumbo, or chats and at least 8 inches under ties. It is not very effective in its use on track ballasted with crushed stone of 2-inch or 2½-inch size or larger of quality which closely packs or cements in track. Where conditions are right, satisfactory results are obtained, the ballast shoulder is loosened up, and the vegetation can be easily removed by section forces and better drainage afforded.

Weed Burners

The development of weed burning machines was carried out in a large measure from the experience of the Yazoo & Mississippi Valley Railroad. While these machines proved to be very efficient labor-saving devices and more economical than any other method of destroying weeds during their early development, weed burning machines with many improvements developed in the past six or seven years have resulted in greater efficiency of operation. Two different makes are used now most extensively, the Fairmont and the Woolery.

Most satisfactory results can be obtained by commencing operations about May 1st, and operating the machine at such speed as will give the vegetation a thorough scorching, repeating the performance within sixty days. With such operation it is possible to keep the entire ballast section practically clean during growing season.

Reports indicate fire damage to cross-ties and other structures is experienced infrequently, but some claims of relatively small amounts have had to be settled by Claims Department on different lines for burning pastures and woods. However, at least one railroad has experienced so much trouble with fire damage that the use of the equipment was abandoned. Fire fighting equipment usually consists of section gang with motor car and trailer following behind the weed burner. On the trailer car a water tank or several barrels containing approximately 400 gallons and a small gas engine water pump fitted up so tank or barrels can be filled from streams adjacent to the track. The pump is also used to provide pressure in two lines of ordinary garden hose equipped with nozzles. This outfit, although somewhat crude, is very effective and develops a considerable saving over handling the water with buckets.

There is considerable variation in the performance of the different machines even of the same make on the same territory and a wider difference between performance of machines on extreme Northern and Southern lines.

A small type burner has recently been developed to be handled by motor car section crew; it is designed especially for branch line service or for the burning of passing, side and yard tracks.

Reports from railroads to whom inquiry was directed indicate weed destroying equipment and cost data for operation as follows:

Performance Data

Non-Poisonous Powder—*(Atlacide)*

Railroad	*Quantity Used*	*Cost of Chemical*	*Cost of Container*	*Cost of Application*	*Total Cost*	*Year Used*
A. T. & S. F.	20,000 lbs.	.....	..	.....	$2770.00	1929
A. T. & S. F.	350 lbs.	5¢ per lb.	5¢	10¢ per lb.	70.00	1930
A. T. & S. F.	1,500 lbs.	5¢ per lb.	5¢	10¢ per lb.	300.00	1931

Steam Weed Destroyer

Railroad	*Miles Treated*	*Total Cost*	*Average Cost per mile single treatment*	*Year*
A. T. & S. F.	1328.6	$17,743.26	13.40	1928
A. T. & S. F.	1535.6	18,946.21	12.34	1929
A. T. & S. F.	3408.3	31,840.53	9.34	1930

Reports discontinued in 1931

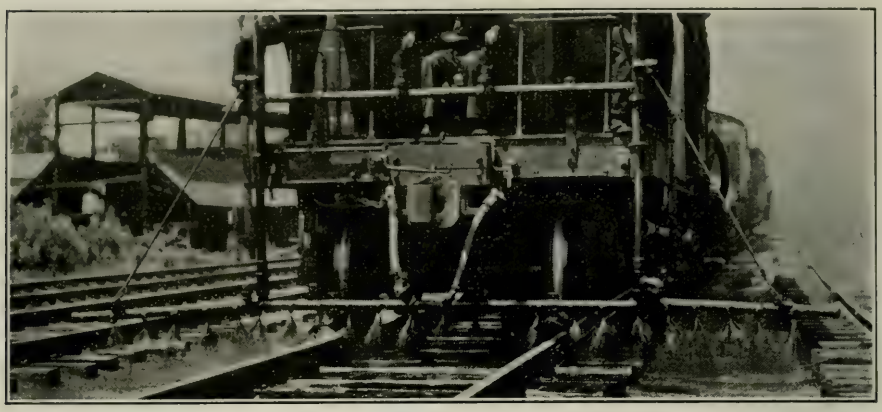
Weed Eradication—Chemicals

Railroad	*Total Miles Treated*	*Total Gallonage Used*	*Average Gallonage Appld. per mile*	*Average cost per mile*	*Kind of Chemicals*	*Remarks*
A. T. & S. F.	8251.40	1,416,887	170.1	$39.94	Poisonous	1929–1932
Ill. Cent.	21480.68	1,151,093	53.6	29.81	"	1918–29
Sou. Pac.	1600.00	80,000	50.0	17.04	"	1931
Tex. & Pac.	2243.60	201,297	89.7	40.79	"	1928–31

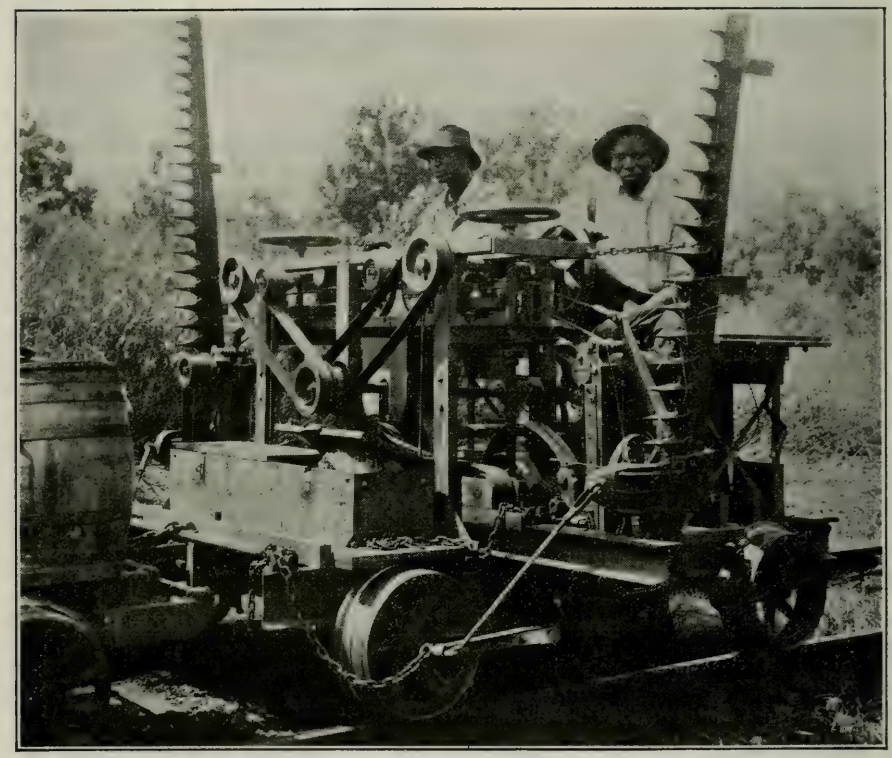
Weed Eradication—Flame Burner Machine

Railroad	*Miles Burned*	*Distillate Used Gals.*	*Average Cost per Track mi.*			
N. Y. N. H. & H.	309.25	25994	13.82	1932	Performance	
Soo Line	2359.5	102204	4.98	1932	"	3-Burnings
Mo. Pac.	8051.0	.....	3.10	1932	"	
Mo. Pac.	1839	.....	4.21	1932	"	
Mo. Pac.	9569	.....	3.84	1931	"	
Mo. Pac.	3562	.....	5.26	1931	"	
So. Pac.	3868	.....	2.969	1931	"	3-Burnings
Ill. Cen.	550	.....	7.28	1931	"	2-Burnings
Ill. Cen.	203	.....	5.28	1931	"	1-Burning
Ill. Cen.	2506	144375	3.61	1930	"	1-Burning
M. & St. L.	3661	225234	6.54	1932	"	
M. & St. L.	3346	226500	8.66	1931	"	
Tex. Pac.	2035.4	.....	6.48	1925 to 1930		

Average yearly performance.

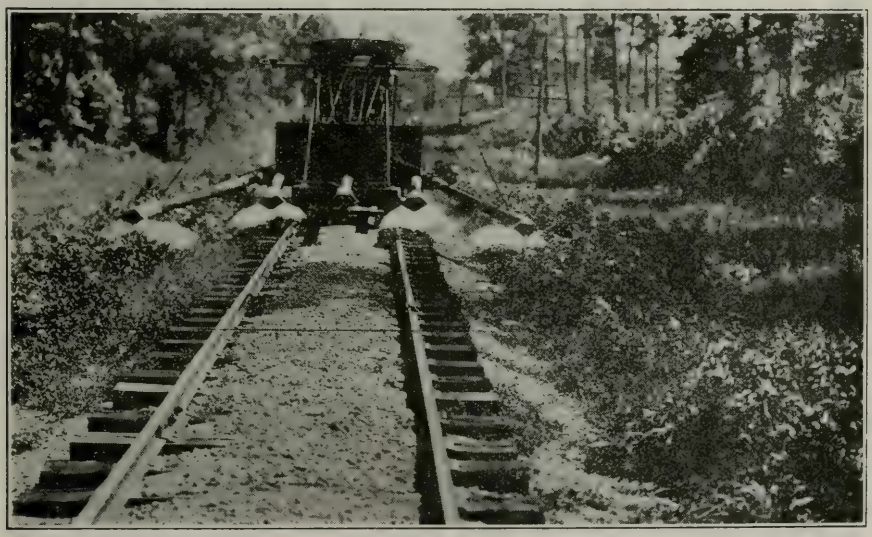


Method of Applying Chemicals or Oil.



Track Mowing Machine with Lower Blades Elevated.

Oven Type Weed Burner.



Extension Burner Type of Weed Burner.

Appendix F

(13) TRACK WELDING EQUIPMENT (a) OXY-ACETYLENE; (b) ELECTRIC ARC

J. M. Trissal, Chairman, Sub-Committee; M. D. Bowen, Walter Constance, J. J. Davis, Wm. Elmer, C. L. Fero, R. J. Gammie, Paul Hamilton, F. W. Hillman, Harry Homans, Jack Largent, E. H. Ness, J. G. Sheldrick, L. J. Turner, G. R. Westcott, Fred Zavatkay.

The Maintenance of Way Department of a railway may employ welding for building up rail ends, repairing frogs and switches, and welding bridge members and structural steel work. As the type and requirements of equipment necessary to properly handle the welding of bridge members and structural steel is determined by the particular conditions involved, they will not be discussed in this report.

The conditions involving selection of proper equipment for building up rail ends and repairing frogs and switches are essentially the same on all railroads and will be discussed in this report.

Two distinct processes of welding are employed in handling this work, namely, the oxy-acetylene torch and the electric arc. The oxy-acetylene torch is generally considered preferable for cutting purposes, whereas the electric arc is the only method that has been successfully employed in welding manganese. The relative economies of the two methods of welding are subject to considerable deviation and depend largely upon the organization and methods of operation. The following facts, however, are generally applicable in studying the difference in cost of work performed by the two methods.

1. Oxy-acetylene welding requires less equipment and lower initial investment than does electric welding.
2. Due to limitations of capacity of electric welding equipment in general use, the number of welders that can be conveniently used at one location is larger with oxy-acetylene welding than with electric welding.
3. The welding equipment necessary for oxy-acetylene welding is much more portable than is equipment for electric welding.
4. Oxygen and gas required for oxy-acetylene welding are more expensive than gasoline and oil necessary to drive portable electric welding machinery or electrical energy for driving motor generator electric welding machinery.
5. To obtain the maximum economy from electric welding equipment, it must be portable and kept in service as nearly continuously as practicable.

The organization and methods employed in oxy-acetylene welding have been developed over a period of years and the process is in extensive use for repairing carbon steel frogs and switches, butt welding joints and building up battered rail ends. Torches and gas regulators have been greatly improved, and for the latter work one of the Eastern roads is now using double tip flame. It is claimed that the speed of the depositing metal is thus nearly doubled, and the heat does not have time to penetrate so deeply into the rail head. They hope to develop a three-tip torch in the near future to still further increase the speed and reduce the cost. The usual round welding rod becomes a flat strip for this work.

On some roads, in building up battered rail ends, it is customary, after heating the rails with the torch, to drive the metal in from the sides, which raises the surface and reduces the amount of metal to be added. On some roads the welders beat down the applied new metal with a hand hammer, using a straight edge from time to time to test the evenness of the work. On other roads a helper strikes a flatter held by the welder, and sometimes the welder lays down the torch and strikes the flatter held in his left hand with a heavy hammer wielded by his right.

There are two general types of electric welding equipment, namely, the alternating current type and the direct current type. The alternating current type of welding overcomes to a large extent the objection to electric welding equipment not being portable. Electrical energy is generated at 440 volts or higher and is then transmitted over relatively small sized cables for a considerable distance where it is transformed to the voltage required for welding. In this manner it is possible for one welding machine at single setting to supply energy necessary for welding over a section of track a mile long. In this type of equipment, however, the cost and maintenance of cables are considerable and there is always the problem of possible theft of cables unless a watchman is left with the machine at all times. Also it is generally considered that welding with alternating current is more difficult and not as satisfactory as welding with direct current. When 440 volt potential is to be used for the transmission of energy, through cables which lie along the right-of-way and are connected and disconnected by men who are, in all probability, not electricians, the problem of personal hazard becomes one of the most serious objections to this method of welding.

In direct current welding the current is supplied to the arc by means of relatively large cables, usually 4/0. There are many machines now in use, of constant voltage type, having cables up to 1500 feet in length but as the loss of energy involved is considerable, a later trend is toward cable lengths not exceeding 300 or 400 feet, used with a variable voltage machine, thus reducing the energy loss, but introducing the necessity of frequently changing the location of the machines.

Electric welding machines in the past have commonly been mounted on portable trucks either self-propelled or non-self-propelled, on standard gage with crosswise trucks for removing the machine from the track.

To overcome the heavy energy loss inherent in the use of long cables and at the same time avoid labor and time in making frequent changes in location of machine, a recent development is the practice of mounting the welding generator on a tractor which is capable of moving along the right-of-way and over bridges and culverts to any desired location.

Fig. 1 and 2 show the type employed on the Lehigh Valley, where a 300 ampere welding generator is mounted inside of a tank type tractor which is 15 ft. long, 32 in. wide and 37 in. high. The size of the tractor was determined by the conditions to be met when running along the side of the tracks through various cuts and on fills. The motive power for operating the tractor is supplied from a 7½ KW auxiliary generator which supplies electrical energy to two 5 HP. motors which are geared directly to the tractor tracks. When the tractor is not being propelled along the right-of-way the output of this 7½ KW generator is available for driving grinders and other auxiliary equipment. The 300 ampere welding generator is driven from a 65 HP. gasoline engine and supplies ample current for the operation of one arc.

The welding and ground cables employed with this particular machine are of 3/0 size, each 150 feet long, which permit the machine to supply energy for welding 12 joints in each track without moving the machine when work is being performed on 39-ft. rails.

The auxiliary generator enables the use of electrically driven grinders which are used for surface grinding and cross-slotting of rail ends.

With this particular equipment a force of one welder, one grinder operator, one laborer and one flagman is employed. The grinder operator moves the tractor when it is necessary and sees that proper voltage and current values are obtained from the generators for the operation of welding and grinding equipment.

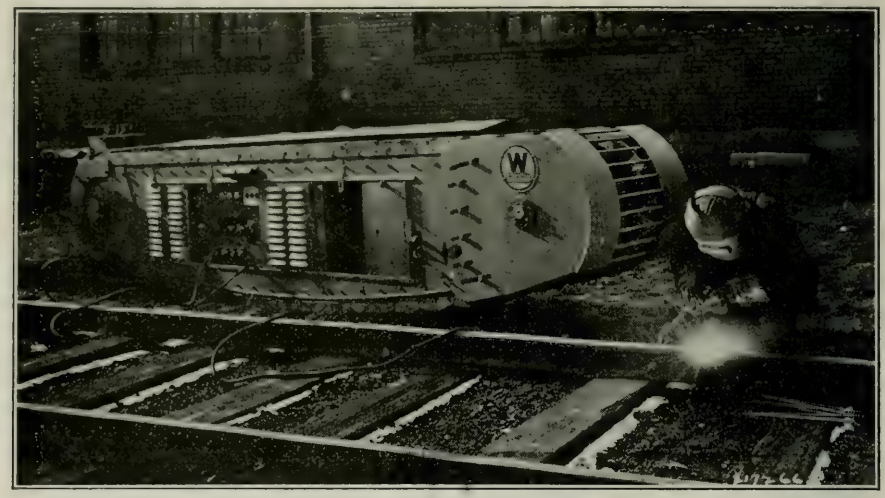


Fig. 1.—Tank Type Tractor with Arc in Operation.

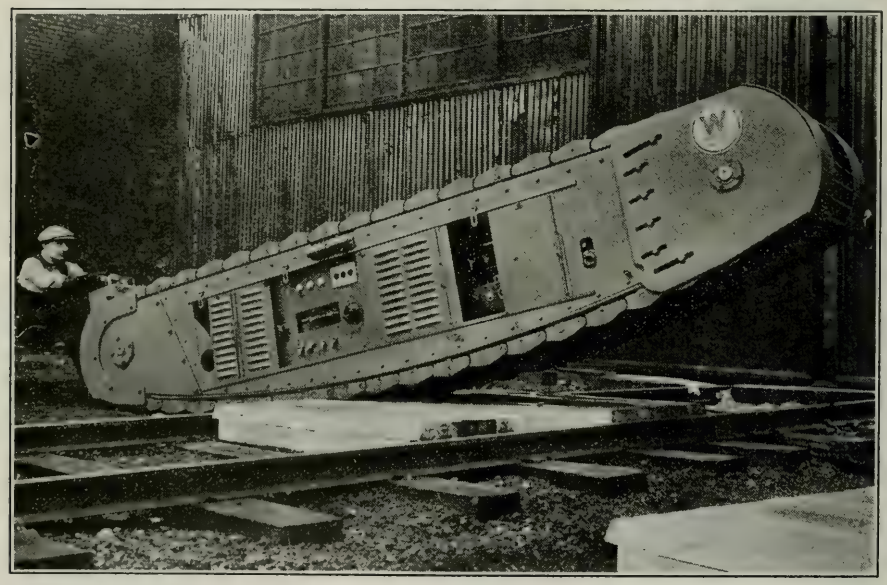


Fig. 2.—Tank Type Tractor Mounting Loading Platform.

Fig. 3 and 4 shows the type of tractor mounted welding equipment used on the DL&W. This equipment consists of a 300 ampere welding generator, belt driven from a 25 HP. gasoline engine which also furnishes power for the propulsion of the track type tractor upon which the generator is mounted. One hundred and fifty feet lengths of 4/0 cable are used for welding and ground leads which permit the welding of approximately 12 joints in each track without the movement of the tractor.

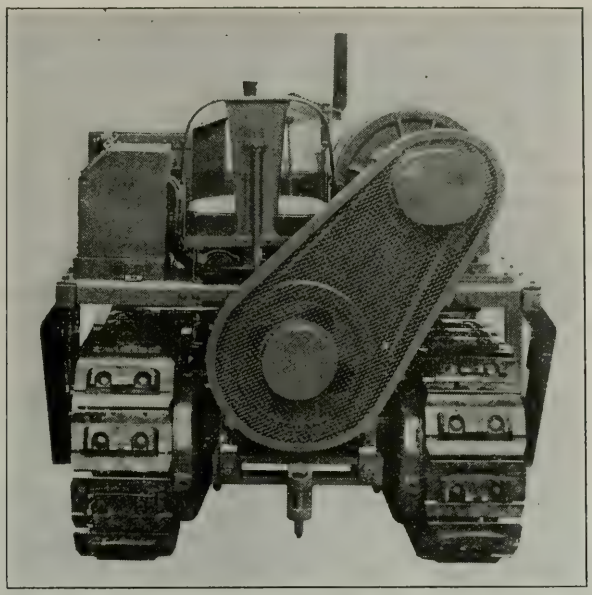


Fig. 3.—Method of Mounting Welding Equipment on Track Type Tractor.

Fig. 4.—Track Type Tractor with Arc and Grinder in Operation.

In this particular equipment there is no generator for supplying electrical energy for accessory operation and grinding is handled with gasoline driven surface and cross grinders. Two of these tractor welders are operated at the same location and the force employed consists of one foreman, two welders, one grinder and one flagman.

The width of the machine is 58½ inches but the cuts and fills encountered on the DL&W will enable the machine to operate successfully along the side of the right-of-way without interfering with train movements.

Fig. 5 shows the type of tractor mounting employed on the Illinois Central's Chicago Terminal where the welder is used exclusively on frog and switch work. In this equip-

ment a 300 ampere machine is mounted on a truck and equipped with 4/0 welding and ground cables 150 feet long. Due to the fact that all frogs and switches on the Chicago Terminal are accessible to automobile roads, this equipment has proved entirely satisfactory. The truck type mounting greatly facilitates the movement from point to point when they are some distance apart. However, use of this equipment has a limited field as it can not be used with any great degree of success on rail end work and must be used on a terminal so located that the frogs and switches to be welded are accessible to automobiles. Other roads in various parts of the country have made use of similar equipment.

Fig. 6 shows type of mounting employed on the C&O where the machine is moved from one general location to another by loading it on a specially designed trailer car and pulling it along the track. This equipment consists simply of a 200 ampere gasoline driven machine mounted on pneumatic tired wheels, which can be readily loaded on the

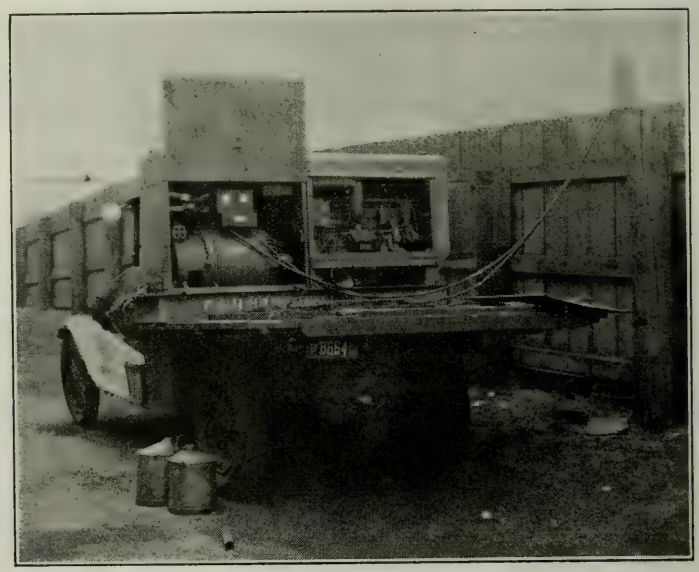


Fig. 5.—300 Ampere Welder Mounted on Automobile Truck.

Fig. 6.—Electric Welder with Rubber Tires Mounted on Specially Designed Trailed Car.

trailer. The use of pneumatic tired wheels permits of easy movement over the rails and along right-of-way for joint welding around yards. Two 3/0 cables 125 feet in length, are sufficient for the machine to handle 9 joints in each track from one location.

Various other methods of mounting of welding equipment have been developed and unquestionably more will be developed in the future but it is believed that the results on the roads mentioned above indicate a high degree of portability can be obtained by various methods of mounting of direct current welding equipment.

In all classes of welding equipment it is essential that the electric arc be stable and relatively flexible. In order to do this it is necessary that a constant voltage be maintained and current surges eliminated as far as practicable. If the arc should be extinguished the voltage should immediately come back to its full open circuit value in order to facilitate the re-striking of the arc.

These characteristics are obtained in various ways in the various machines and a study of the characteristics of the individual machine will illustrate accurately wherein any differences may lie.

Obviously the most satisfactory machine will be the one wherein the most universal characteristics are obtained with the least possible adjustment, and it should be borne in mind that the operators of the welding equipment, in all probability, are not electricians and the fewer adjustments it is necessary for them to make, the more satisfactory will be the operation.

The types of connections which are made to the welding equipment vary greatly with the various models and the connector which makes the best contact in the easiest manner with the maximum of safety is the connector which is best adapted to this service. It is essential that good contact be maintained in all cases as a considerable drop in voltage will exist due to any poor connection.

Length of cables involved is of considerable importance as too long a cable will bring about excessive voltage drop and cause poor welding conditions as well as overloading of the machine. There is set forth below a tabulation indicating what the voltage drop will be with various sizes and lengths of cable with various currents flowing through them.

Voltage Drop with Various Currents (77° Fahr.)

	150 AMPS	*200 AMPS*	*250 AMPS*	*300 AMPS*
2— 150 ft. 3/0 cables	2.84	3.78	4.73	5.67
2— 200 " " "	3.78	5.04	6.30	7.56
2— 250 " " "	4.73	6.30	7.88	9.45
2— 300 " " "	5.67	7.56	9.45	11.34
2— 350 " " "	6.62	8.82	11.03	13.24
2— 400 " " "	7.56	10.08	12.61	15.13
2— 150 " 4/0 "	2.25	3.00	3.75	4.50
2— 200 " " "	3.00	4.00	5.00	6.00
2— 250 " " "	3.75	5.00	6.25	7.50
2— 300 " " "	4.50	6.00	7.50	9.00
2— 350 " " "	5.25	7.00	8.75	10.50
2— 400 " " "	6.00	8.00	10.00	12.00
2— 500 " " "	7.50	10.00	12.49	14.99
2—1000 " " "	14.99	19.99	24.99	29.99
2—1500 " " "	22.49	29.99	37.48	44.98

National Electrical Code *continuous* current carrying capacities.

3/0 cables 175 amps.
4/0 cables 225 amps.

It is the belief of the Committee that the subject of equipment for handling electric arc welding in the Maintenance of Way Departments of railroads is a very important

one and that it will become of greater importance in the near future. The Committee plans to obtain definite operating statistics so that next year its report will contain information relative to both the oxy-acetylene and the electric arc method of building up rail ends and performing frog and switch welding.

Appendix G

(15) THE USE AND MAINTENANCE OF PAINT SPRAYING EQUIPMENT WITH OUTLINE OF TYPICAL ORGANIZATION FOR VARIOUS CLASSES OF WORK

N. M. Trapnell, Chairman, Sub-Committee; W. A. Batey, G. J. Ermentrout, Robert Faries, C. L. Fero, Paul Hamilton, J. S. Huntoon, E. H. Mills, T. M. Pittman, Harry Slabotsky, H. W. Stetson, J. B. Trenholm.

The present report deals with the results of a test of the application of bridge paint by means of the spray gun and the hand brush, made by an Eastern railroad in February, 1933. The test was made primarily to determine the comparative qualities of certain bridge paints. However, much of the data collected is of value in comparing the two methods of application.

The test was made on a deck plate-girder bridge, using six different bridge paints and six primers. In order to conduct the test with equal fairness to all paints used, they were all applied to the same side of the bridge, but on different spans, and were all subject as nearly as possible to the same general conditions.

The first part of the test was made with paint spraying equipment, the same well-known make of spray gun having been used exclusively. The second part of the test was conducted with hand brush application. The spray application was made on the north side of the bridge, beginning at the west end and working east. The brush application was also made on the north side, east of the spray application. In both cases one gallon of each manufacturer's primer was used, and one gallon of each manufacturer's "Black" was next applied over its own primer.

The data recorded for each paint and primer included the weight per gallon, cost per gallon, area covered, man-hours per gallon, man-hours per 100 square feet, cost per 100 square feet, air pressure used, atmospheric temperature, ease of application, general appearance, and weather conditions at the time of application. Most of the detailed data recorded is given in the supplementary table.

Only the actual time consumed in applying the paint was recorded, because, as stated previously, the purpose of this test was to determine the comparative qualities of different paints, and a fair comparison of cost would be impossible if the time consumed in cleaning, moving scaffolding and delays not caused by the paint itself, were charged against it.

A summary of the averages contained in the supplementary table of data, showing a comparison between the two methods of application, is as follows:

	Primers		*Paints*	
	Spray	*Brush*	*Spray*	*Brush*
Avg. weight per gallon—lb.	14.5	14.5	8.8	8.8
" cost per gallon	$1.79	$1.79	$1.31	$1.31
" area covered—sq. ft. per gallon	398.17	385.03	230.01	436.17
" man-hrs. per gallon	.185	1.483	.193	2.165
" " " " 100 sq. ft.	.052	.396	.091	.508
" cost per 100 sq. ft.	$ .453	$ .722	$ .724	$ .625
" air pressure—pounds	23	...	26	...
" atmospheric temperature	26°	37°	23°	33°

The primers used varied in weight from 11.1 to 18.1 lb. per gallon, and in price from $1.20 to $3.00 per gallon. The paints used varied in weight from 7.9 to 9.7 lb. per gallon, and in price from $.74 to $1.85 per gallon. It is therefore considered that the averages shown in the foregoing table are fairly accurate as regards the effect of quality on area covered and cost of application.

The increase or decrease in area covered, labor to apply, and cost of application by the spray method compared to the hand brush method, is as follows:

	Primers		*Paints*	
	Amount	*Per Cent*	*Amount*	*Per Cent*
Difference in area covered—sq. ft. per gallon	131.4 inc.	34.2% inc.	206.16 dec.	42.2% dec.
Difference in man-hours per gallon	1.298 dec.	87.6% dec.	1.972 dec.	91.4% dec.
Difference in man-hours per 100 sq. ft.	.344 dec.	86.9% dec.	.417 dec.	82.3% dec.
Difference in cost per 100 sq. ft.	$.269 dec.	36.2% dec.	$.099 inc.	15.9% inc.

It will be noted that, in the case of the primers, there is no question of the economy of the spray method. The area covered is 34 per cent greater, the time required for application is 87 per cent less, and the cost of labor and material is 36 per cent less, than for the brush method.

However, in the case of the paints, the result appears to be somewhat different. Although the time required for application is 82 per cent to 91 per cent less, the total cost of application per 100 sq. ft., including labor and material, is 16 per cent greater for the spray method than for brush painting. This is accounted for by the fact that the area per gallon covered with brush application is 42 per cent greater than that covered with the spray, and therefore, the amount of paint applied per 100 sq. ft. is 42 per cent less.

The decrease in the amount of paint applied per unit area with the hand brush method indicates a considerably thinner paint film than that obtained with the spray method. Also, the character of the surface of the brush film is not as smooth and uniform as that of the spray film, due to the minute grooves made by the bristles of the brush. In view of these facts, it is highly probable that the spray film will prove to be the most durable and may be more economical in the end than the brush film, although the cost of application per unit area is 16 per cent greater.

It is concluded that the results of this test demonstrate fairly conclusively the economy of spray painting as compared to the hand brush method, when applied to large surfaces. It should be borne in mind that the weather conditions during the test were rather severe, with a strong wind blowing most of the time. This tends to increase the paint consumption with the spray method, as much of it is blown away and lost.

The cost of cleaning the surfaces to be painted was practically the same for both methods of application. Also, there was little difference in the cost of erecting and moving scaffolding. Where extension guns are used the cost of handling scaffolding is considerably less for spray painting than for hand brush painting. The only items of cost incident to spray painting which do not obtain with brush painting are the setting up, maintenance, and operation of the air compressor and maintenance of the paint-spraying equipment. However, these are more than offset by the saving in man-hours on large jobs.

It is recommended that the present report be received as supplementary information to the report submitted by this Sub-Committee in 1931.

TABULATED RESULTS OF TEST OF BRIDGE PAINT APPLICATION

Legend	Weight per Gallon	Cost per Gallon	Area Covered Sq. Ft.	Man-Hrs per Gallon	Man-Hrs per 100 Sq. Ft.	Cost per per 100 Sq. Ft.	Air Pressure Pounds	Atmospheric Temperature	Application	Finish	Remarks
Spray Application											
Primer—A	13.7 lbs.	$1.45	367.58	.167	.045	$.422	30	10°	Good	Flat	Weather clear and cold.
Primer—B	14.3 lbs.	1.20	387.75	.117	.052	.340	30	10°	Good	Gloss	Weather clear and cold.
Primer—C	15.5 lbs.	3.00	454.89	.200	.044	.685	20	30°	Good	Flat	Weather cloudy, mild and windy.
Primer—D	18.1 lbs.	2.30	418.68	.183	.044	.575	20	35°	Good	Gloss	Weather cloudy, mild and windy.
Primer—E	11.1 lbs.	1.20	364.43	.208	.057	.363	20	35°	Good	Gloss	Weather cloudy, mild and windy.
Primer—F	14.5 lbs.	1.58	395.79	.233	.059	.435	20	38°	Good	Gloss	Weather cloudy, mild and windy.
Average	14.5 lbs.	$1.79	398.17	.185	.052	$.453	23	26°			
Paint—A	9.7 lbs.	$1.15	217.64	.200	.092	$.584	20	30°	Fair	Flat	Wrinkled at bottom. Weather cloudy, mild and windy.
Paint—B	8.5 lbs.	1.10	151.58	.192	.127	.801	20	30°	Bad	Gloss	Wrinkled at bottom. Weather cloudy, mild and windy.
Paint—C	8.9 lbs.	1.85	278.57	.217	.078	.711	40	18°	Good	Flat	Weather cloudy and cold.
Paint—D	9.1 lbs.	1.80	139.26	.167	.120	1.363	25	20°	Bad	Flat	Wrinkled badly. Weather cloudy and cold.
Paint—E	7.9 lbs.	.74	393.29	.250	.064	.225	25	20°	Good	Gloss	Weather cloudy and cold.
Paint—F	8.5 lbs.	1.25	200.02	.133	.067	.665	25	20°	Fair	Flat	Wrinkled and splotchy. Weather cloudy and cold.
Average	8.8 lbs.	$1.31	230.01	.193	.091	$.724	26	23°			
Brush Application											
Primer—A	13.7 lbs.	$1.45	472.28	1.466	.310	$.493	--------	40°	Good	Gloss	Weather cloudy, mild and windy.
Primer—B	14.3 lbs.	1.20	380.96	1.166	.306	.499	--------	40°	Good	Gloss	Weather cloudy, mild and windy.
Primer—C	15.5 lbs.	3.00	314.06	2.067	.658	1.350	--------	35°	Bad	Flat	Pulled hard. Weather cloudy, mild and windy.
Primer—D	18.1 lbs.	2.30	380.96	1.366	.358	.817	--------	35°	Fair	Gloss	Weather cloudy, mild and windy.
Primer—E	11.1 lbs.	1.20	380.96	1.433	.376	.541	--------	40°	Good	Gloss	Weather cloudy, mild and windy.
Primer—F	14.5 lbs.	1.58	380.96	1.400	.367	.634	--------	30°	Good	Flat	Weather cloudy, mild and windy.
Average	14.5 lbs.	$1.79	385.03	1.483	.396	$.722	--------	37°			
Paint—A	9.7 lbs.	$1.15	412.58	2.233	.542	$.604	--------	35°	Fair	Flat	Weather cloudy, mild and windy.
Paint—B	8.5 lbs.	1.10	380.96	1.667	.437	.551	--------	35°	Fair	Gloss	Weather cloudy, mild and windy.
Paint—C	8.9 lbs.	1.85	380.96	2.432	.638	.868	--------	30°	Bad	Gloss	Pulled hard. Weather cloudy, mild and windy.
Paint—D	9.1 lbs.	1.80	380.96	2.432	.638	.855	--------	30°	Bad	Gloss	Pulled hard. Weather cloudy, mild and windy.
Paint—E	7.9 lbs.	.74	595.88	2.333	.391	.359	--------	35	Good	Gloss	Weather cloudy, mild and windy.
Paint—F	8.5 lbs.	1.25	465.69	1.899	.407	.512	--------	30°	Good	Gloss	Weather cloudy, mild and windy.
Average	8.8 lbs.	$1.31	436.17	2.165	.508	$.625	--------	33°			

Appendix H

HAZARDS OF SPRAY PAINTING

There has always been a certain hazard to health in the handling of paints and painting materials regardless of whether it was applied by brush or spray. Poisoning due to lead contained in paints, also to the thinners used has been recognized as a hazard to health long before air was used. A review of the poisonous ingredients in paints, lacquers, enamels, etc. indicates that the most serious hazards are from lead which is a constituent of many paints, benzol which has been used extensively as a thinner and silica used almost altogether in connection with spraying enameled ware.

In the early days of spray painting the theory was advanced that the fine diffusion of paint materials by the spray was such that inhalation resulted in great danger to the operator and in some cases where paint spraying equipment was first used indoors without the use of properly ventilated booths this theory seemed to be borne out in fact. While no statistics are available it appears that insofar as outdoor painting is concerned the spray gun offers no greater hazard than the use of the brush because the natural air currents are adequate to dispose of the fumes. Where spray painting is done indoors with paints containing lead or benzol there is a possible health hazard unless proper ventilation is provided. The National Safety Council has conducted what was probably the most extensive investigation ever made as to the probable hazards of spray painting and a means of overcoming them. A comprehensive report of that committee was published by the National Safety Council in 1927. A very brief summary of the findings of the committee follows:

It was determined that benzol poisoning might occur from the continual use of the material as a solvent or thinner in painting materials either through the application of brush or spray. It was further found that the hazard of benzol poisoning could be eliminated through the installation of efficient air conditioning equipment in rooms where painting was carried on. It was also found that the hazard of poisoning from benzol could be very materially reduced by the use of ordinary masks or respirators, or eliminated entirely by the use of especially designed respirators. Their investigation determined that all cases of benzol poisoning were confined to workmen engaged in interior painting.

The comments in regard to hazards of lead poisoning are practically the same as those with reference to benzol poisoning. Also, the same methods of eliminating the hazards are recommended, and as with the benzol poisoning all workmen who showed any trace of lead poisoning were engaged in interior painting.

It is apparent from the National Safety Council's investigation that there are three sources of health hazards encountered in spray painting, namely, inhalation of benzol fumes, lead particles or silica dust.

It is apparent from this report that there is but little danger from the benzol fumes or lead where painting is done outdoors. Such fumes are quickly dissipated or diluted by contact with fresh air. Lead poisoning occurs through continuous inhaling of lead particles and not through the application on the hands, face or body, as there is but little danger of lead poisoning absorbed from paint coming in contact with the skin. Silicosis due to inhalation of dust particles of silica rarely occurs in railroad work as silica is probably not present in paints used on railroad buildings of other structures, the only hazard from silica being in sand blasting. When this work is done outdoors, however, such hazard is practically negligible.

The Monthly Labor Review (May, 1929) of the Bureau of Labor Statistics, United States Department of Labor, has the following comments to make in regard to hazards of poisoning from the use of paints or coatings:

"Poisoning or disability from the use of paint or coatings arises mainly from three sources; namely, from the use of lead and its compounds, from benzol, and from siliceous materials.

"The lead compounds are used in the form of lead chromates in pigments, and carbonates, sulphates, and sulphides as paint bases. Poisoning from lead compounds in paints may occur from:

(a) Inhalation of dust from sandpapering one coat of paint preparatory to applying another.
(b) Entry of dust into either the respiratory or digestive system from mixing dry white lead with oil.
(c) Inhaling fumes from burning off old paint.
(d) Inhaling dust arising from lead paint dried on overalls and drip cloths.
(e) Breathing of lead paints nebulized by spraying and suspended in the air, which may find their way into both the alimentary canal and the respiratory system.
(f) Using glazing putty containing lead compounds.

"Of these six possibilities the result may be either contamination of food by unwashed hands, entrance of lead into the alimentary canal by placing objects in the mouth while working with lead compounds, or the direct inhalation of lead in dust form into the lungs where it can be directly absorbed into the blood. In spray painting the last named type of absorption is the most likely, and authorities state that this type produces the greatest toxic effect because the lead is absorbed directly by the blood without having to go through the liver, while lead which passes through the alimentary canal does go to the liver and much of it is thrown off through the excretory system.

"Benzol poisoning results from the continual breathing of benzol fumes. These fumes can not be removed from the air by any method not involving chemical means. It has been stated that a worker continually breathing air containing 100 parts or more of benzol in 1,000,000 parts of air is working under a substantial hazard. This is due to the fact that benzol taken into the system forms a chemical combination with the body tissues, especially the marrow of the bones, where it affects the formation of red blood corpuscles. The National Safety Council's report on benzol (May, 1926) states that 'generally cases of acute poisoning from inhalation are either rapidly fatal or respond favorably to treatment with more or less complete recovery within a short period. * * * In chronic benzol poisoning we find a wholly different picture. The onset is insidious, the early symptoms are generally overlooked, and it is not until the condition becomes relatively grave that it receives medical attention.' "

Silica, as used in various enamels and glazes, also presents certain dangers. Breathing sufficient siliceous material causes what is known as silicosis, an ailment resulting from the accumulation of considerable quantities of insoluble dust material in the lungs. This dust is not absorbed by the blood and its presence causes irritation and later what is termed "fibrosis."

The following measures are suggested for overcoming dangerous practices in the use of paints:

(a) Greasing unprotected portions of the body, to make any material collecting thereon easily removable.
(b) Thorough washing and the brushing of the finger nails, as well as avoiding the habit of placing anything in the mouth during work hours.
(c) Protection of food and of street clothing from dust and spray.
(d) Cleanliness of working clothes.
(e) Teaching employees of the proper use of the gun.

(f) Equal protection of all employees who are working within 30 feet of the spray gun where no direct exhaust is available.

(g) Wet sanding instead of dry sanding wherever possible.

(h) Reduction of the pressure on pressure containers to the lowest point consistent with speed of application required.

(i) Reduction of the pressure used to break up the material to the lowest point consistent with the nebulization required.

(j) Careful use of the gun at the proper distance from the work.

(k) Use of nontoxic materials of nonirritating character wherever possible.

State regulations regarding spray painting, also taken from The Monthly Labor Review, follow:

"Massachusetts, Michigan, and Wisconsin control the process of spray coating by a code of special rules and regulations, while California, New York, and Pennsylvania have tentative codes of rules and regulations. In New York the code is still in the hands of an advisory committee; in California and Pennsylvania the codes have been submitted to the public but have not yet been approved by proper authority and therefore do not now have the force of law.

"Illinois, New Jersey, and Ohio have comprehensive laws dealing in considerable detail with means of protecting the health and welfare of workmen, and which apply generally to any hazardous process or condition in manufacturing plants. These laws guide inspection of spraying equipment and conditions in the three states.

"In Maryland and Wyoming, and in the United States Congress, bills are pending to regulate the process of spray painting.

"The Colorado Department of Labor has formulated a set of rules and requirements as a guide for factory inspectors in certifying spray-painting equipment in the State.

"Connecticut, Delaware, Iowa, Maine, Minnesota, Missouri, New Hampshire, Rhode Island, Washington, and West Virginia have general statutes concerning ventilation or sanitation which would probably apply to any spray painting where the materials used contained lead, benzol, or other toxic material.

"In Ohio the industrial commission is empowered to supervise the life, health, safety, and welfare of employees. Under this authority, the commission has issued supplementary rules for the guidance of factory inspectors in making or issuing specific orders when inspecting spray-coating equipment. These rules for the inspectors operate only as a guide to the inspector and do not in any sense apply as law to spray operations in establishments in the State. When the inspector issues a specific order to the employer, however, the order has the effect of law. In Tennessee the general law covering ventilation is pointed out by the State department of labor as its only recourse at present in dealing with the problems of spraying paint. The State has made some efforts toward the formulation of special rules and regulations applying to spray painting, but no definite results have been obtained up to this time. In Utah a similar condition exists. The industrial commission of that State points out that the provision of their workmen's compensation act which obligates the employer to do what is reasonably necessary to protect the life, health, safety, and welfare of workmen is the only provision at present covering in any way the subject of spray painting.

All of the statutes mentioned above appear in Bulletin No. 370 of the United States Bureau of Labor Statistics. The Bulletin, however, does not contain special rules and regulations which have the force of law.

A

Appendix I

(16) ORGANIZATION FOR THE USE AND MAINTENANCE OF BALLAST CLEANING MACHINES AND CONDITIONS UNDER WHICH EACH PARTICULAR TYPE MAY BE USED (INCLUDING MOLES, SCREENS, LOCOMOTIVE CRANES, AND PLOWS USED IN CONJUNCTION WITH BALLAST DISCERS)

Wm. Elmer, Chairman, Sub-Committee; Walter Constance, W. O. Cudworth, J. F. Donovan, Robert Faries, F. S. Hewes, G. W. Hunt, J. S. Huntoon, C. H. Morse, Fred Zavatkay.

Since our report in Vol. 33 of the Proceedings, page 183, there has been completed and placed in service a two-sided ballast cleaning machine which operates on a border and the intertrack space, or on two intertrack spaces simultaneously, as desired. Fig. 1 shows the cleaning unit, consisting of a 65-ft. 105-ton all-steel gas-electric car behind which are coupled two standard 50-ft. flat cars equipped with dirt-disposal machinery. Any kind of locomotive of sufficient capacity may be used for pulling the cleaner. A fourth unit required is some sort of car for supplies, spare parts, welding and cutting apparatus, electric and compressed air drills, etc., for quickly making emergency repairs on the job.

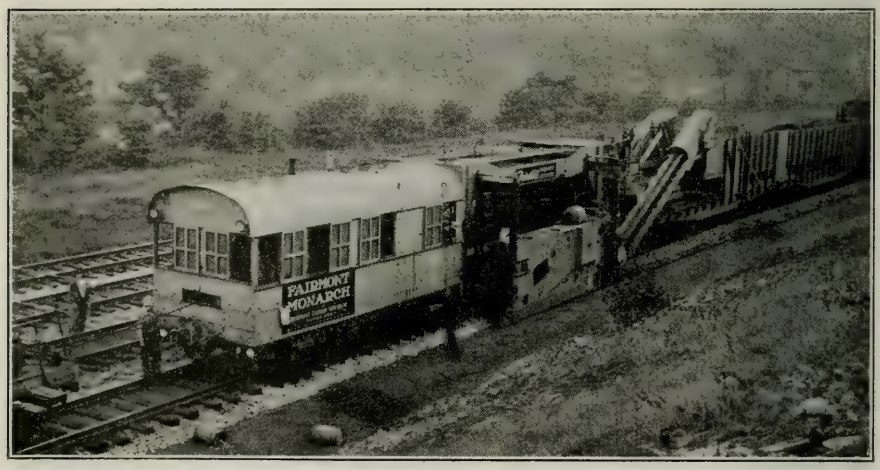


Fig. 1.

The ballast cleaner frame and structure (Fig. 2) are electrically welded, mounted on two 4-wheel trucks spaced 54 ft. center to center. In operation, the locomotive takes position with its brakes set, about 500 ft. ahead of the cleaner, which hauls itself forward by reeling up a steel cable attached to the locomotive.

Rock ballast is picked up on each side from the border or center ditch as the case may be, and screened by two cleaner boxes 30 inches wide, 7 ft. high and 21 ft. long. These 15-ton boxes are hung in wells midway on each side of the machine, within standard A.R.A. clearance. To clean ballast they are moved out and in, lowered and raised, with hydraulic cylinders actuated by oil at 300 lb. pressure per square inch.

Each cleaner box has two vertical in-gathering wings 30 inches high, mounted on the front end flush with the bottom of the box. Each wing is separately controlled by a hydraulic cylinder. The opening between wings can be varied from 36 inches to approximately 60 inches. Thus all ballast between ties of adjacent tracks where tie ends are not less than 38 inches or more than 64 inches apart, can be taken into the cleaner boxes. Either wing can be moved in or out to maintain correct distance from short or long ties, without stopping.

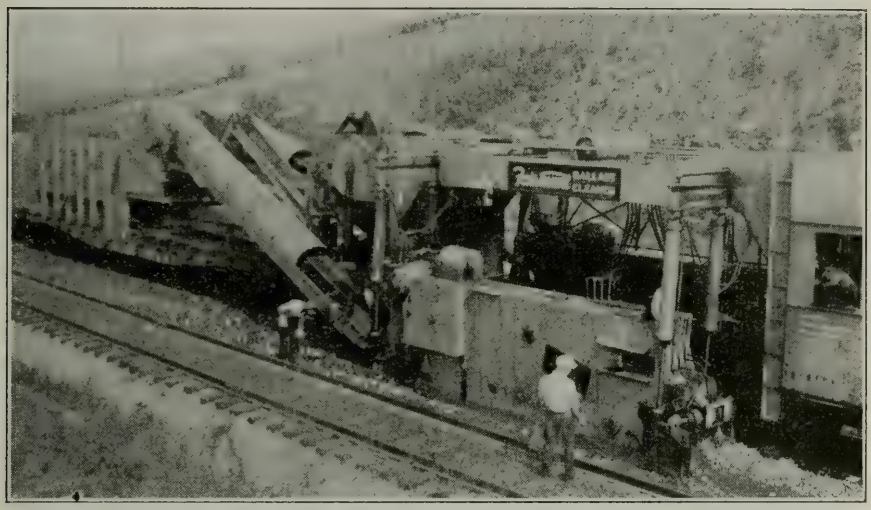


Fig. 2.

All foul ballast is removed from the tie ends, and about one inch is undercut below the ties, by a "step-shaped" projection in the lower wing section which is furnished according to individual railroad requirements. This insures good clean ballast surrounding and underlying the ends of ties after the machine passes.

Ballast is cleaned by passing up an incline over manganese steel grates or screens. It is moved by a manganese steel conveyor chain with flights or paddles every 12 inches, run at a speed of 150 ft. per minute by a 50 HP. electric motor. The flights rub and roll the foul ballast over the grates with a jerky, vibratory action which shakes the dirt loose and drops it through the screen back on the roadbed.

This loose dirt on the roadbed is plowed level, compacted, and the excess dirt picked up by a conveyor which delivers it at the rear of the cleaner box to a 20-inch belt conveyor which carries it into a hopper on the forward end of the 2-car dirt unit.

The cleaned ballast is deposited on the prepared roadbed surface and machine-shaped or dressed to the desired contour, whether center ditch or border.

The two flat cars are fitted with steel-lined 8-ft. walls and together can store about 150 cu. yds. of dirt, enough for 1500 to 4000 ft. of track if cleaning on both sides. Dirt is stored only when working in cuts or other places where it cannot be thrown over the roadbed shoulder.

Most of the time, dirt falls through the hopper to a lower level, upon a 36-inch belt conveyor 22-ft. long, which may be swung out on either side of the car at right angles, passing the dirt across one adjoining track and wasting it over the roadway bank.

Where there is no suitable dumping place, a two-way dragline scraper hauls the dirt back into the cars. When full, the cleaner moves ahead to the nearest spot where dumping is permissible, and starts cleaning ballast while the dirt cars are discharging, thus avoiding idle time while dumping.

The 36-inch discharge conveyor has ample capacity to handle both the dirt from the cleaner and that brought out of the dirt cars by the reversed dragline scraper. When the cars are emptied the cleaner train backs up and resumes cleaning and storing dirt at the first scene of operations.

The ballast cleaning car has a total of 435 HP. in gasoline engines, distributed as follows: 175 HP. to generate current for 11 electric motors, one of 30 HP. operating the 18 oil-pressure cylinders; 120 HP. for the towing hoist; 110 HP. for the 2-drum dragline scraper.

During the past summer this machine, while working on a 4-track section of a busy Eastern railroad cleaned in three weeks, working two 8-hour shifts a day, 328,728 ft. of intertrack space and 142,797 ft. of border. One foot of center ditch is charged as equal to two feet of border. The total is, therefore, 400,136 ft. of equated intertrack space in three weeks, Sundays excluded, a daily average of 22,230 ft. of equated intertrack space. The best day saw 32,903 feet cleaned. A 200-day working season (eight calendar months) at the average rate for this three weeks, would give an annual production of 4,446,000 ft. of center ditch, which is 105 miles monthly and 842 miles per year.

Including dirt handling equipment installed on purchaser's flat cars, the machine costs $125,000. Operated on a contracting basis in 1933, the over-all cost per foot to the railroad company, including supervision, train crew wages, locomotive rental and expenses, insurance coverage for casualty, property and liability, complete disposal of all dirt, and all charges for ballast cleaning, was 4.17 cents for center ditch and 2.12 cents for border.

Under railroad ownership and operation there are possibilities for still lower costs by reduction of overhead through distribution over the output of a full working season, and elimination of some insurance charges.

If this ballast cleaner were self-propelled, costing $175,000, it is estimated the cost per foot would be reduced 20 per cent, and output increased about 10 per cent.

The operating crew consists of a general foreman and two 8-hr. shifts of seven men each. There is a shift foreman; one operator each for the two cleaner boxes, towing winch, and dragline scraper; one laborer each for the ballast shapers at rear of the two cleaner boxes.

A portion of our former report on the subject "Plows used in conjunction with ballast discers" brought out little information. In answer to its questionnaire, the Committee received no information on plows used in conjunction with ballast discers. "There are plows and there are discers, but apparently they have not yet been brought into conjunction. Quite a number of discers are in service which were made by bolting discer attachments on to the sides of track motor cars. These are not very effective, but there are on the market heavy outfits to be operated at a slow speed with powerful special motor cars and they do excellent work in gravel ballast. A car is now being developed which will have a plow in conjunction with a discer and this arrangement will undercut the ends of the ties, throw the ballast out with the discs and permit the water to drain out. After a period of two or three weeks has elapsed, another trip will be made using the discs to throw the ballast back against the ends of the ties and reshape the border."

Since that time a continuous period of experimentation and development has produced a Ballast Drainage Car with scarifiers and bladers, adapted to work in stone ballasted shoulders.

Fig. 3 shows the machine in position for road movement, with all parts within the A.R.A. limits. Fig. 4 shows the machine in working positions, and Fig. 5 is a closeup of the scarifying wing.

On each side are two separate "wings", the front wing for scarifying, and the rear for blading. Either wing is ready for immediate use by simply connecting the cable of pneumatic hoist, and releasing safety chains.

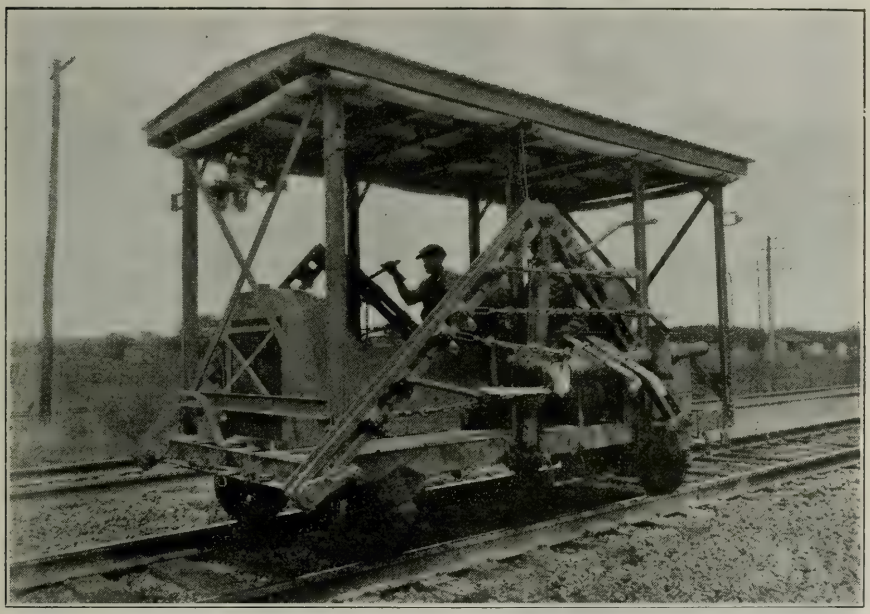


Fig. 3.—Showing Ballast Agitator in Travel Position.
(Arms Raised and Lowered by Air)

None of the wings need additional weight to hold them down while scarifying or blading; all are ruggedly built of heavy castings and structural steel electrically welded into solid units of adequate weight and strength.

Using scarifiers, the machine makes three to five trips, each time ploughing a deeper layer of ballast. The scarifier points loosen the pieces of rock from surrounding dirt, rolling and shoving the mixture outward against a stop plate. Being lined like the edge of a plowshare, the gangs of scarifiers wedge through opposite shoulders with minimum traction, 10 points cutting easily because a furrow is already open beside each.

This leaves ballast piled near the toe line for drying out a few days if muddy (and the crib is full and rail well anchored). Rains at this stage help to wash dirt out. When dry, the rock is bladed back in two trips, to approximate shoulder section. The first blading places the upper and cleaner ballast against the end of ties. The second cut slopes the outer and lower shoulder, which is further cleaned by rains.

It will be seen that much dirt is rubbed off and sifted down in the process of plowing ballast out, then blading it back. The drier the ballast, the better the cleaning. So far most effort has been toward getting the water out of a maximum mileage of track.

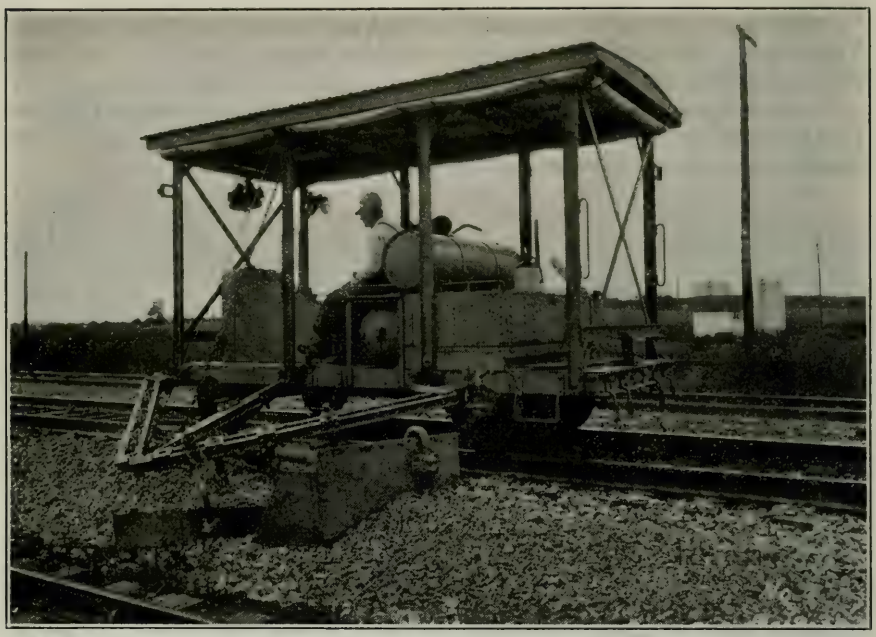


Fig. 4.—Showing Ballast Shaping Blades.

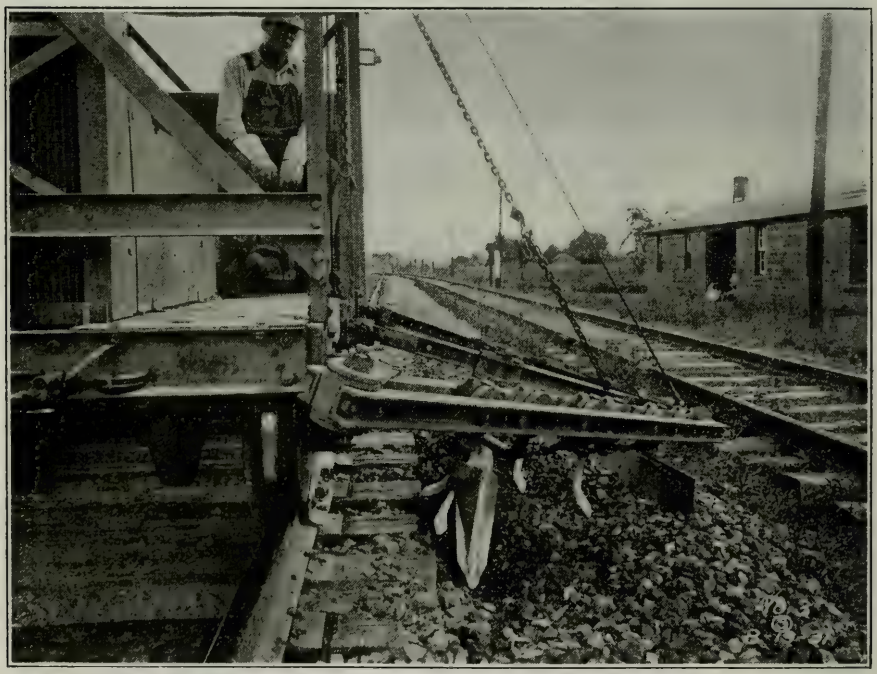


Fig. 5.—Indicating Location of Ballast Agitating Forks.

REPORT OF COMMITTEE XII—RULES AND ORGANIZATION

E. H. Barnhart, *Chairman;*
F. W. Armistead,
M. M. Backus,
W. C. Barrett,
D. P. Beach,
L. D. Beatty,
Richard Brooke,
H. L. Browne,
P. D. Coons,
W. O. Cudworth,
J. L. Downs,
J. T. Fitzgerald,
H. W. Graham,
A. B. Griggs,
H. C. Hayes,
E. G. Hewson,
A. A. Jackson,
B. R. Kulp,
R. E. Warden, *Vice-Chairman;*
H. A. March,
S. H. Osborne,
F. R. Puder,
W. A. Radspinner,
W. B. Stimson,
F. B. Wiegand,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully presents herewith report covering the following subjects:

1. Revision of Manual, collaborating with appropriate committees (Appendix A).

The Committee offers for approval and printing in the Manual the changes outlined in Appendix A, the same to be substituted for the existing subject-matter.

2. Rules for the guidance of employees of the Maintenance of Way Department, with special reference to:

(a) Maintenance of bridges, collaborating with Committees VIII—Masonry, and XV—Iron and Steel Structures (Appendix B).
(b) Maintenance of telegraph and telephone lines and appurtenances, collaborating with committee appointed by Telegraph and Telephone Section (Appendix C).
(c) Maintenance of terminal structures other than buildings, collaborating with Committees XIV—Yards and Terminals and XXIII—Shops and Locomotive Terminals.

2–a. The Committee offers for approval and printing in the Manual Rules 1150 to 1164 inclusive, as shown in Appendix B—Rules for Maintenance of Bridge–Masonry and composite structures. These rules have the approval of Committees VIII—Masonry and XV—Iron and Steel Structures.

2–b. The Committee offers as information in Appendix C rules for maintenance of telegraph and telephone lines and appurtenances. These rules have been prepared by a sub-committee of the T&T Section and are submitted as particularly applying to Maintenance of Way employees. The Committee requests that members of the Association who are interested in this phase of Maintenance of Way work, carefully go over these rules and submit to the Committee any criticism or suggestions.

2–c. The Committee has no further rules to offer on this subject.

3. The Committee submitted as information last year appropriate titles for Assistant Engineers, in all departments. This information was collected after considerable investigation and study and the membership was appealed to for criticisms and suggestions. Since the submission of this information no criticisms or suggestions have been received. The Committee, therefore, submits, in Appendix D, these titles for approval and printing in the Manual.

4. The Committee offered as information last year a number of rules on fire prevention as applying to the Maintenance of Way Department. These rules have been revised and rearranged to meet some criticisms received and they are now offered in Appendix E for approval and printing in the Manual. These rules have the approval of the National Board of Fire Underwriters and Railway Fire Protection Association.

Respectfully submitted,

The Committee on Rules and Organization,

E. H. Barnhart, *Chairman.*

Appendix A

(1) REVISION OF MANUAL

P. D. Coons, Chairman, Sub-Committee.

RULES FOR THE INSPECTION OF BRIDGES, TRESTLES AND CULVERTS

General (p. 847, 1929 Manual)

Present Form

1353. (1st sentence) These bridge inspectors shall forward to the..... in (duplicate)
(triplicate) .....on the proper form provided, a report of each bridge, trestle or culvert inspected, enumerating in detail the parts of each structure inspected, giving the conditions found in each individual part.

Proposed Form

1353. (1st sentence) These bridge inspectors shall forward to the..... in (duplicate)
(triplicate) ..... on form 1110 Revised or 1110–A as appropriate, a report of each bridge, trestle or culvert inspected, enumerating in detail the parts of each structure inspected, giving the conditions found in each individual part.

Field Inspection (p. 853, 1929 Manual)

1359. (1st sentence) The Division Bridge Inspector shall each day, after a structure is inspected, send to the..... .....a report on approved form in (duplicate)
(triplicate) showing defects, if any, giving a minute description of said defects.

1359. (1st sentence) The Division Bridge Inspector shall each day, after a structure is inspected, send to the..... .....a report on form 1110 Revised or 1110–A as appropriate in (duplicate)
(triplicate) showing defects, if any, giving a minute description of said defects.

* Forms (p. 859, 1929 Manual)

* Forms

1415. Form to be used by Division Bridge Inspector for general inspection of all bridges, trestles and culverts should be printed in books of 100 or more leaves, each leaf being perforated and having a carbonized back. The backs of the books should be stiff cardboard or linen and size should not exceed 4½ inches by 6½ inches.

* Forms—Eliminate

1415. Eliminate

* Forms not yet submitted

* Eliminate.

Appendix B

(2–A) RULES FOR MAINTENANCE OF BRIDGES—MASONRY

A. B. Griggs, Chairman, Sub-Committee.

1150. Driftwood or other débris must not be permitted to accumulate around the base of bridge masonry.

1151. All obstructions to proper drainage in the channel must be removed. If obstructions are caused by a faulty channel, changing channel should be given consideration.

1152. Where scouring or undermining of bridge masonry is found, riprap or other forms of protection must be installed.

1153. Where foundations are badly undermined or otherwise endangered, protection shall be provided for the structure.

1154. Where examination reveals weakness of masonry from any cause, such conditions must be reported.

1155. Where arches or culverts are subjected to excessive scouring or undermining, protection must be provided.

1156. Where masonry is subjected to the action of ice or other abrasion causing disintegration, protection work of proper design must be installed.

1157. Where masonry is founded on timber, previously under water which subsequently becomes exposed to the air, proper foundation must be substituted.

1158. Where movement has become restricted at expansion joints, they must be repaired to allow the joints to function as designed.

1159. Where indication of failure of arch rings occurs as evidenced by cracks or flattening of the arch, temporary support must be provided until permanent repairs can be made.

1160. Drains or "weep holes" in bridge masonry must be kept open to insure full operation of the drainage system.

1161. Inadequate drainage of bridge masonry must be remedied.

1162. Bridge seats that have become weakened through deterioration or overload must be replaced.

1163. Areas of masonry that have become deteriorated must be repaired prior to reaching an extent endangering the strength of the structure.

1164. Joints in stone masonry must be kept well pointed. Before pointing, all loose material must be removed and the joints well-moistened.

Appendix C

(2–B) RULES FOR MAINTENANCE OF TELEGRAPH AND TELEPHONE LINES AND APPURTENANCES

W. C. Barrett, Chairman, Sub-Committee.

General

A–1. The following rules covering outside communication plant are for the guidance of maintenance of way employees and are based upon specifications and instructions contained in the Manual of Recommended Practices of the Telegraph and Telephone Section. (For details concerning the construction and maintenance of outside communication plant, see Section 1 of the Manual.)

Clearances

B–1. Aerial Lines Along Railroads.—All poles shall be set so that the minimum horizontal clearance of any wire, guy or other attachment will be eight feet from the outer edge of the nearest main track rail. Under normal conditions with poles carrying ten-pin crossarms, this minimum clearance will be obtained by setting poles thirteen feet from the rail.

B–2. Where it is impracticable to obtain the clearance specified above, the poles may be set with a minimum horizontal clearance of eight feet from the outer edge of the nearest main track rail, but the lowest attachment in such cases shall be at least twenty-five feet above the rails. Where the poles have a horizontal clearance of from ten to thirteen feet inclusive, the lowest crossarm should be not less than twenty feet above the rails. The minimum vertical clearance for any crossarms should be ten feet above the ground.

B–3. Poles may be set at a minimum horizontal clearance of seven feet from the outer edge of the nearest track rail, providing the lowest attachment is at least twenty-five feet vertically above the rails. At loading sidings space shall be left for a driveway.

B–4. At private and farm crossings the clearance shall be such that the wires or other attachments will not interfere with the free use of such roads. Over driveways leading to private residences the minimum clearance shall be fifteen feet. At private or farm crossings used for the passage of wagons and farm machinery a clearance of over fifteen feet may be necessary. At crossings used only by cattle or pedestrians, the clearance may be reduced safely to ten feet.

B–5. When a cable attachment is made to a metal bridge, the cable and messenger shall be insulated from the bridge structure. The type of insulating attachment best suited for use in any particular situation will depend upon local conditions, but in most cases it will be sufficient to support the messenger on wood blocks, clamped or bolted to the bridge structure.

B–6. Trees should be trimmed so as to give at least a four-foot clearance from all wires. If the trees are not located on a railroad property permission shall be obtained from the owner before trimming. If permission cannot be obtained, the fact should be reported.

B–7. Care should be taken to avoid contact, either direct or by means of material or tools, with wires on communication pole lines designated by a stripe painted on the crossarm or by the use of a different form of insulator from the others on the pole line.

B–8. Telltale poles or other structures should not be erected so as to interfere with communication wires or so as to endanger men working on such structures by coming in contact with wires.

B–9. If poles or wires that are broken obstruct tracks, clear same immediately, exercising proper care in handling wires to avoid interruption to service on wires that are intact. If power wires are carried on the line, do not touch or come in contact with any wires except by the use of properly insulated tools.

B–10. Worthless junk, such as scraps of old iron wire, must be buried or otherwise satisfactorily disposed of. If left around, scraps of wire may be thrown in the line by persons passing by.

B–11. Aerial Crossings.—Poles or towers supporting the crossing span shall, unless physical conditions prevent, have side clearance of not less than twelve feet from the nearest track rail except that at sidings a clearance of not less than seven feet may be allowed. At loading sidings sufficient space shall be left for a driveway. Where necessary to provide safe operating conditions which require uninterrupted view along the tracks for signals, signs, etc., the parties concerned shall cooperate to provide greater clearances than those specified above.

B–12. Report all vertical clearances above rails that do not conform to:

(a) The clear headroom between the lowest wire, cable, guy or suspension strand and the top of rail shall be not less than twenty-seven feet, except where the wires or cables are paralleled in the same highway by a trolley contact conductor at a lower level, the clearance between such wires or cables and the top of rail may be reduced to twenty-five feet.

(b) Where the distance from the nearest crossing support to the farthest track rail exceeds seventy-five feet, the clearance specified above shall be increased by two-tenths of a foot for each ten feet in excess of seventy-five feet; provided, however, that the above distance from the nearest pole to the farthest track rail need not be considered more than one-half the span length.

B–13. Unless approved by the railroad company, attachments to railroad steel bridges shall not be made by devices that require the drilling or cutting of the bridge structure or the removal of rivets, and the attachments shall be made so that wires, cables and suspension strand will not be in metallic contact with the bridge structure.

B–14. The clearance of any conductor from the face of the abutment shall be not less than three feet for steel bridges.

B–15. Cables or twisted pair wires and their suspension wires may be attached directly to the face of the abutment if located not less than twenty-four inches below the elevation of the bridge seat, and they shall provide suitable clearances for pedestrians, vehicles, etc., as may be necessary.

B–16. The clearance between any conductor attached to the bridge in open construction, and any portion of the bridge structure shall preferably be not less than six inches, except where this is impracticable, the value may be reduced to not less than three inches.

B–17. The clearance between any conductor not attached to the bridge and any portion of the bridge structure shall preferably be not less than one foot, except where this is impracticable, the value may be reduced to not less than six inches.

Underground Construction

C–1. The underground system shall be so located as to be subject to the least amount of disturbance. Care shall be exercised to avoid catchbasins, pipes, or underground structures which have been installed or are planned for the future.

C–2. The top of all conduit protection, except as hereafter specified, shall generally be located at a depth of not less than three feet six inches below the base of the rail. Where this is impracticable, or for other reasons, this clearance may be reduced by agreement between the parties concerned. In no case, however, shall the top of the conduit

protection extend higher than the bottom of the ballast section which is subject to working or cleaning.

C–3. Where unusual conditions exist or where proposed construction would interfere with existing construction a greater depth than specified above may be required.

C–4. Where physical and chemical conditions will permit, a conduit consisting of not more than two iron pipes, not exceeding three inches in diameter, or two creosoted wood ducts, not exceeding four and one-half inches square, used for telegraph, telephone or other communication lines, may be laid in the ground beneath railroad tracks without any form of protection at a minimum depth of eighteen inches below the base of the rail unless the worked ballast section of the roadbed exceeds eighteen inches, in which case the conduit shall be laid below the ballast section.

C–5. In no case shall the conduit structure be less than eighteen inches below the surface of the ground.

C–6. When underground conduit construction crossing tracks terminates on terminal poles immediately adjoining the tracks, or in manholes, handholes, etc., which project above the surface of the ground, the side clearance, unless physical conditions prevent, shall be not less than twelve feet from the nearest track rail, except that at sidings a clearance of seven feet may be allowed. At loading sidings sufficient space shall be left for a driveway. Manholes and handholes shall in no event be located closer than seven feet from the nearest rail.

C–7. Where the conduit system parallels the railroad right-of-way it is desirable to locate it as far as practicable from the railroad tracks. Where it is impracticable to locate the conduit system three feet or more horizontally from the nearest rail, special types of construction shall be used or special precautions taken.

C–8. Where necessary to prevent caving, the sides of trench shall be supported with suitable planks and bracing. No bracing shall extend above the base of the rail or be attached in any way to the rails or ties.

C–9. The trench shall be backfilled with earth to the subgrade line, using the better material next to the conduit structure. Stones shall not be placed next to the conduit structure. If any large stones that were removed are replaced, they shall be replaced in a vertical position. Excavation below the bottom line of the trench shall be backfilled with good earth and well tamped. Track ballast shall be replaced under railroad supervision.

C–10. All surplus material remaining after the work has been finished shall be removed, and if disposed of upon railroad property shall be placed under railroad supervision.

C–11. When excavating for any purpose, or working the ballast section of the roadbed, precautionary measures should be taken to avoid damage to underground communication facilities.

General Rules

D–1. Report all cases of prospective foreign line construction which will cross over or under or paralleling their own lines and all unsafe conditions at existing wire crossings.

D–2. Bring to the attention of the properly designated official such matters as may come to their knowledge which in any way would be advantageous to the company's service or which might adversely affect the company.

D–3. Telephone dispatching and message circuits on communication pole lines are generally designated by the letter "D" for the dispatcher's circuit and the letter "M" for the message circuit marked on the crossarm between the two wires of each circuit. Where circuits are so designated, users of portable telephones should be instructed to make connections with the dispatcher's or message telephone circuits only at points where circuits are so designated.

D–4. Water must not be used to extinguish electrical flames. Sand, dry earth, or fire extinguishers approved for electrical fires should be used. A stream of water must not be played on a "live" third rail or electric wire.

D–5. Employees shall not climb into wires when not aware of their operating voltages. They must be able to identify supply circuits which are sometimes located on the lower crossarms.

D–6. If wires hang low over any track, street or thoroughfare, leave sufficient men to guard them, until raised to proper clearance.

D–7. Be on the alert to detect trespassers who may be shooting or stoning cables, wires, insulators, etc. Take necessary action to prevent damage to plant and make proper report of details to properly designated official for further handling.

D–8. The removal of dry grass and inflammable débris or refuse from around poles will reduce the fire hazard. In burning refuse material, select a location where the communication lines or other property will not be damaged.

D–9. The carrying of blow torches, open flames, lighted cigars, cigarettes or pipes into or near the openings of manholes is strictly prohibited.

D–10. Spreaders, ditchers and other roadway machinery must be operated so as not to interfere with the communication plant.

D–11. As grass and forest fires may seriously damage the communication plant, it is essential that every effort be made to prevent them and to cooperate fully with National and State forestry fire prevention measures.

D–12. Wire connections to water or other pipes, ground rods, etc., should not be loosened or removed, and where such conditions are found they should be reported at once to proper authority. The function of such wires is to provide return paths for various currents transmitted over the lines and in connection with electrical protection to provide drainage for currents resulting from crosses with foreign circuits or from lightning. This removal or loosening of these connections may mean serious injury to employees using telephone or working telegraph wire at that location, in case of crosses with foreign circuits or from lightning discharges.

D–13. Prompt report should be made to the properly designated official of the following conditions whenever noted:

Poles that are badly rotted, burned, split or otherwise considered unsafe.
Poles that are leaning.
Poles that have been washed out.
Dead trees, branches or vines overhanging or leaning toward the lines.
Fires which occur in close proximity to the line.
Any wire or rubbish that may be hanging on the wires.
Broken or decayed crossarms.
Pins that may be broken or pulled out of crossarms.
In case of a general line prostration such as a storm break, report nature, location and extent of damage.
In the case of foreign supply line crossing failures obstructing the tracks of the railroads, no attempt shall be made to remove the high voltage wires until it is definitely known that the current is shut off. When this has been ascertained, such wires shall be removed from obstructing the track and the owner notified.
Manholes where gas is detected escaping from it.
Cables that are hanging loose from messenger wires as a result of cable rings or other supports failing.

Appendix D

(3) APPROPRIATE TITLES FOR ASSISTANT ENGINEERS

Richard Brooke, Chairman, Sub-Committee.

	Duties of Position	*Reporting to*	*Proposed Title*
(1)	In charge of office engineering work in office of Chief Engineer	Chief Engineer or Assistant Chief Engineer	Office Engineer
(2)	Special investigations, studies, estimates and reports	Chief Engineer or Assistant Chief Engineer	Special Engineer
(3)	In charge of reconnaissance and of location on an entire system, or region of a large system	Chief Engineer	Locating Engineer
(4)	In charge of a reconnaissance or location on a specific project	Locating Engineer	Assistant Locating Engineer

	Duties of Position	*Reporting to*	*Proposed Title*
(5)	In charge of construction on an entire system, or region of a large system	Chief Engineer	Construction Engineer
(6)	In charge of large construction projects	Construction Engineer	Assistant Construction Engineer
(7)	In charge of a specific project, such as ten miles of new line or equivalent	Construction Engineer or Assistant Constr. Engineer	Resident Engineer
(8)	General inspection of construction work	Construction Engineer	Construction Inspector
(9)	In charge of office engineering work in office of Construction Engineer	Construction Engineer	Office Engineer, Construction
(10)	Special maintenance investigations	Chief Maintenance Officer	Special Engineer, Maintenance
(11)	* Preparation of plans and estimates and supervision of field and office engineering work	Division Engineer	Assistant Engineer, Maintenance
(12)	Inspection of track and roadbed	Chief Maintenance Officer or an Assistant	Maintenance Inspector
(13)	Inspection of bridges and/or buildings on an entire system, or region of a large system	Chief Maintenance Officer or Bridge Engineer and/or Building Engineer	General Bridge and/or Building Inspector
(14)	Special bridge and/or building investigations, studies, estimates and reports	Chief Maintenance Officer or Bridge Engineer and/or Building Engineer	Special Engineer, Bridges and/or Buildings
(15)	Bridge design (particular projects)	Bridge Engineer or an Assistant	Bridge Designer
(16)	Bridge erection on a specific project	Bridge Engineer	Assistant Engineer, Bridge Erection
(17)	Building design and erection	Building Engineer	Assistant Engineer, Buildings
(18)	Water service, design, construction and/or maintenance	Chief Water Service Officer	Assistant Engineer, Water Service
(19)	Miscellaneous valuation work	Valuation Engineer	Assistant Engineer, Valuation

* This title was adopted by the Convention in March, 1931, and printed in Bulletin 347, page 29 (Revisions and Additions to the Manual).

Appendix E

(4) RULES FOR FIRE PREVENTION AS APPLYING TO MAINTENANCE OF WAY DEPARTMENT

H. C. Hayes, Chairman, Sub-Committee.

General

33. Employees must give full co-operation to fire prevention measures and be familiar with location and use of nearest fire alarms.

Division Engineers

302. They must see that employees under their jurisdiction are properly instructed in fire prevention rules, alert in decreasing fire hazards and exacting in the maintenance and operation of fire fighting apparatus. When locating buildings and structures, they will see that attention is given fire prevention.

Supervisors of Track

316. They must give particular attention to fire hazards from adjoining property and from structures erected on railway property by lessees.

317. They must see that those under their supervision do not obstruct fire roads, fire hydrants and hose houses.

318. They must see that no lumber, ties, piling or other inflammable materials are piled in close proximity to any important building and that automobiles or trucks are not parked in a manner which constitutes a fire hazard.

319. They must know that their foremen understand and observe fire prevention rules.

Supervisors of Bridges and Buildings

374. They must give particular attention to fire hazards where the risk is extreme, such as oil houses, paint shops, wood coal chutes, and cotton platforms.

375. They must make proper reports to superiors of any unguarded fire hazards.

376. They must see that those under their supervision do not obstruct fire escapes and exit passages thereto, fire doors, hose reels, fire hydrants, fire roads, and hose houses.

377. They must see that all sprinkler systems and fire fighting apparatus under their jurisdiction are maintained in accordance with the National Fire Underwriters Code.

378. They must arrange through their superior officers for the proper cooperation of all municipal fire departments.

379. They must make recommendations for fire stops when necessary, and for the removal of any fire hazards.

379–A. They must see that inflammable materials are stored so as to confine any fire to the place of origin.

379–B. They must know that their foremen understand and observe fire prevention rules.

Supervisors of Water Service

423. They must know that fire pumps and fire lines under their jurisdiction are in proper working condition, and that fire hydrants and hose are always ready for instant use.

424. They must call attention to points where connections might be made to municipal fire mains.

425. They must know that their foremen understand and observe fire prevention rules.

REPORT OF COMMITTEE VI—BUILDINGS

G. A. Rodman, *Chairman;*
A. L. Becker,
G. A. Belden,
G. H. Burnette,
Eli Christiansen,
A. C. Copland,
F. B. Doolittle,
W. T. Dorrance,
Hugo Filippi,
J. N. Grim,
E. L. Haberle,
E. A. Harrison,
L. C. Hinsch,
C. D. Horton,
A. C. Irwin,
F. R. Judd,
E. K. Mentzer,
F. R. Micheal,
R. E. Mohr,
A. H. Morrill,
O. G. Wilbur, *Vice-Chairman;*
E. W. Niblet,
J. W. Orrock,
O. M. Rognan,
A. L. Sparks,
J. A. Stocker,
A. B. Stone,
A. T. Upson,
C. L. Wenkenbach,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully presents herewith report covering the following subjects:

(1) Revision of Manual (Appendix A).

(2) Preparation of Specifications for Railway Buildings (Appendix B).

(3) Remodeling Freight Houses for Accommodation of Truck Door-to-Door Delivery of Freight (Appendix C).

(4) Bus Terminal Buildings, Isolated and in Conjunction with Railway Stations, collaborating with Committee XIV—Yards and Terminals (Appendix D).

(5) Application of stainless and rust-resisting metals to building construction (Appendix E).

(6) Vermin and rat-proofing in buildings (Appendix F).

(7) Relative merits of wood and fireproof roof structures, which should include wood, hollow tile fireproofing, concrete and cement tile, etc. (Appendix G).

(8) Causes of dust explosions in grain elevators and methods of obviating the hazard (Appendix H).

(9) Mill type and other heavy wood construction for railway buildings (Appendix I).

(10) Study the economic value of various basic and composite materials used in building construction and maintenance (Appendix J).

Action Recommended

1. That the changes in the Manual as recommended in Appendix A be approved and the revised text be substituted for that now appearing in the Manual.

2 a.—That the specification for Electrically Operated Freight or Baggage Elevators, previously published in the Proceedings as part of Appendix A, section 29, pages 682 to 688, both inclusive, of Bulletin 354, Vol. 34, Proceedings 1933, be printed in the Manual.

b.—That the specifications submitted with this report as Appendix B be published in the Proceedings as information and for criticism.

c.—That this subject be reassigned.

(3) That the report in Appendix C be received as information and as a final report and the subject discontinued.

(4) That the subject be reassigned as recommended in Appendix D.

(5) That the subject be reassigned as recommended in Appendix E.

(6) That the subject be reassigned as recommended in Appendix F.

(7) That the report in Appendix G on Relative Merits of Wood and Fireproof Roof Structures be received as information.

(8) That the report in Appendix H on Causes of Dust Explosions in Grain Elevators be received as information.

(9) That the subject be reassigned as recommended in Appendix I.

(10) That the subject be reassigned as recommended in Appendix J.

Respectfully submitted,

The Committee on Buildings,

G. A. Rodman, *Chairman.*

Appendix A

(1) REVISION OF MANUAL

G. A. Belden, Chairman, Sub-Committee; A. C. Copland, F. R. Judd, A. L. Sparks, O. G. Wilbur, E. K. Mentzer.

Your Committee recommends the adoption of the following revisions in the subject-matter now appearing in the Manual:

1. Page 316. Section 10–A, Concrete Roofing Tile

First paragraph at top of page reads as follows:

"The joints of large flat tile shall be pointed where necessary so as to provide a smooth surface for the application of the composition roofing, which is to be applied with a high melting point adhesive."

Revision recommended:

"The joints of large flat tile shall be pointed where necessary so as to provide a smooth surface for the application of the roofing."

2. Pages 319 to 327—Section 10–D, Built-up Roofing

Substitute the following revised specifications, dated July 26, 1933, for the specifications now published on these pages:

REVISED SPECIFICATIONS FOR BUILT-UP ROOFING

Section 10–D

BUILT-UP ROOFING

Materials

1. General

The contractor shall furnish all labor, material, tools and equipment necessary to entirely complete the roofing to make the work watertight, and shall leave it in a neat and finished condition.

2. Materials

Pitch.—Pitch shall be the best quality, straight-run American coal-tar pitch, distilled direct from coal-tar and free from water and ammonia. It shall contain not less than 15 per cent nor more than 36 per cent of free carbon. The melting point shall be not below 140 degrees Fahr. nor above 150 degrees Fahr. (A.S.T.M. cube method) and it shall show a flashpoint of not less than 240 degrees Fahr.

Asphalt.—Asphalt shall be a combination of natural asphalt prepared and combined properly in which inherent mineral matter will be permitted but to which no mineral matter shall be added.

For roofs having a slope not greater than 3 inches per foot the melting point shall be between 140 and 165 degrees Fahr. and for roofs having a slope greater than 3 inches per foot, the melting point shall be between 165 and 180 degrees Fahr., as determined by the "Standard method of test for softening point of bituminous materials other than tar products" (ring and ball method) in accordance with the standard methods of the A.S.T.M.

The penetration at 77 degrees Fahr. under a load of 100 grams for 5 seconds shall be not less than 20 nor more than 30. The ductility at 77 degrees Fahr., when a briquette of the material having a minimum cross-section of 1 square centimeter is pulled apart at the rate of 5 centimeters per minute, shall be not less than 10 centimeters for asphalt having a melting point under 165 degrees Fahr., nor less than 3 centimeters for asphalt having a melting point between 165 degrees Fahr. and 180 degrees Fahr. The loss of a 50 gram sample at 325 degrees Fahr. for 5 hours shall not exceed 1 per cent. The penetration of the residue at 77 degrees Fahr. under a load of 100 grams for 5 seconds shall be not less than 10 nor more than 15. The methods of making tests shall be in accordance with the standard of the A.S.T.M., and penetrations are in hundredths of a centimeter.

Asphalt Primer.—Asphalt primer for concrete and gypsum decks shall weigh not less than 7 lb. per gallon and shall be made from asphalt, of the quality specified under "Asphalt" fluxed to the proper consistency. The melting point of the asphalt primer shall be such as will permit the subsequent application of hot asphalt to amalgamate immediately with it.

Roofing Felts.—All felts shall be either 32 or 36 inches wide. They shall be of the kind and weight hereinafter specified. They shall have sufficient pliability to meet the requirements of application. Samples taken from the felts weighing approximately 14 lb. per 108 sq. ft. shall bend flat through 180 degrees without cracking and samples from the felts weighing approximately 60 lb. per 108 sq. ft. shall bend around one-half inch radius through 180 degrees without cracking. A variation of seven (7) per cent from the weights of the felts specified will be allowed. The impregnating compounds shall be of the qualities specified and shall be of the proper consistency for saturating the felts.

Manufactured Roofing.—Manufactured roofing material shall be delivered at the site in the original sealed packages of the manufacturer, and each package shall be wrapped and labeled properly in order that it may be identified easily.

Flashing.—Where flashings, gravel stops and eave trim are to be of metal, they shall be in accordance with the provisions of Section 11, Sheet Metal Work; otherwise they shall be as hereinafter specified.

Gravel and Slag.—Gravel shall be hard, durable, free from clay, loam, and other foreign substances, and shall range from ¼ to ⅝ inch.

Slag shall be granulated furnace slag, free from sand, dirt and other foreign substances, and shall range from ¼ to ⅝ inch.

3. Application

The roof decks shall be clean, smooth, thoroughly dry and free from projections which would injure the roof coverings. All roofing shall be laid smoothly, without wrinkles or buckles, and finished surfaces shall be free from cracks and bubbles.

Before applying the roofing over wood decks, all loose knots and other flaws shall be removed and knot holes and large cracks shall then be covered with tin or other sheet metal nailed in place.

For gypsum or concrete decks, the joints and surfaces shall be made tight and flush, and all loose and uneven surfaces shall be leveled up before the roofing is applied.

Type A–1

Tarred Rag Felt, Pitch and Gravel (or Slag) Over Wood or Pre-Cast Units

1. This type of roofing shall be limited to use on wood or pre-cast gypsum roofs having a slope not greater than 2 inches per foot and on pre-cast concrete roofs having a slope not greater than 1 inch per foot.

2. This type of roofing shall be composed of five layers of not less than 14 lb. tarred rag felt, a minimum of 150 lb. of pitch per 100 sq. ft. and coated with gravel or slag.

3. If on wood, lay one thickness of rosin-sized building paper or unsaturated felt weighing not less than 5 lb. per 108 sq. ft., lapping the sheets at least one inch; if on pre-cast units this shall be omitted.

4. Over the entire surface lay two layers of tarred felt, weighing not less than 14 lb. per 108 sq. ft. per layer, lapping each sheet of each layer 17 inches over the preceding sheet for 32-inch wide felt or 19 inches for 36-inch wide felt, end laps not less than 4 inches. Sheets shall be nailed as often as necessary to hold them in place until the remaining felt is laid. These layers shall be turned up against vertical surfaces not less than 6 inches and securely fastened.

5. Over the two layers of 14 lb. felt apply metal eave strips and gravel stops at all edges of the roof, as specified in paragraph 6, Section 11, Sheet Metal Work.

6. Coat the entire roof surface uniformly with hot pitch, using not less than 25 lb. per 100 sq. ft.

7. Over the entire surface lay three layers of tarred felt, lapping each sheet of each layer 22 inches over the preceding sheet for 32-inch wide felt or 25 inches for 36-inch wide felt, with end laps not less than 6 inches. Hot pitch shall be mopped the full 22 inches or 25 inches respectively on each sheet so that in no place shall felt touch felt, using not less than 25 lb. of pitch per 100 sq. ft. between successive layers. Any nailing necessary shall be done in such a manner that all nails will be covered by not less than two layers of felt. Nails shall be galvanized and shall be driven through tin or zinc caps. These layers shall be cut off at vertical surfaces and thoroughly mopped along the edges.

8. Flashings shall be installed at all intersections of the roof with vertical surfaces, and the plans will show whether sheet metal or felt flashings are to be used.

Where metal flashings are called for they shall be furnished and installed in accordance with paragraph 4, Section 11, Sheet Metal Work and, in addition, the felt and pitch reinforcement shall be installed as follows:

After all plies of roofing have been laid and before application of the slag or gravel surface, the contractor shall set in separately at the angle of the roof deck and vertical surface 3 plies of 14 lb. tarred felt, cemented together with coal-tar pitch. These plies shall extend out on the roof at least 4 inches and up the vertical surface 6 inches. The last ply shall be coated with coal-tar pitch and then the metal base and counter flashing installed as specified in Section 11. The flange of the base flashing on the roof shall be coated with hot pitch into which shall be bedded a 4-inch strip of felt centered over the nailing course. This strip shall be coated with hot pitch into which shall be bedded a second strip of felt 6 inches wide and completely covering the first.

Where felt flashings are called for they shall consist of 3 layers of 14 lb. asphalt felt and a cap flashing of 85-lb. slate surfaced roll roofing. The felt strip shall be cemented to the roof and vertical surface and to each other with an approved plastic roofing cement, reinforced with mineral fiber.

The first strip of felt shall extend 6 inches up the vertical surface and 4 inches out on the roof, the second 8 inches up the wall and 5 inches on the roof and the third 10 inches up the wall and 6 inches out on the roof. Felt strips shall not exceed 10 ft. in length and shall be lapped at least 1 inch at all joints and joints broken. The cap flashing of mineral surfaced roofing shall extend at least 4 inches in masonry walls and down to the roof deck and shall be cemented to the base flashings with plastic roofing cement.

9. Coat the entire roof surface with hot pitch poured from a dipper, using not less than 75 lb. of pitch per 100 sq. ft. and into this while hot embed not less than 400 lb. of dry gravel (or 300 lb. of dry slag) per 100 sq. ft. In cold weather the gravel or slag shall be heated before being applied.

Type A–2

Tarred Rag Felt, Pitch and Gravel (or Slag) Over Homogeneous Roofs Cast in Place

1. This type of roofing shall be limited to use on roofs having a slope not greater than 2 inches per foot.

2. This type of roof shall be composed of 5 layers of not less than 14 lb. tarred rag felt, a minimum of 215 lb. of pitch per 100 sq. ft. and coated with gravel or slag.

3. The entire roof surface shall be coated uniformly with hot pitch, using not less than 40 lb. per 100 sq. ft.

4. Over this lay two layers of tarred rag felt, weighing not less than 14 lb. per 108 sq. ft. per layer, lapping each sheet of each layer 17 inches over the preceding sheet for 32-inch wide felt or 19 inches for 36-inch wide felt, end laps not less than 4 inches. Hot pitch shall be mopped the full 17 inches or 19 inches respectively on each sheet, so that in no place will felt touch felt, using not less than 25 lb. of pitch per 100 sq. ft. between successive layers. These layers shall be turned up against vertical surfaces not less than 6 inches and securely fastened.

5. Over the two layers of 14 lb. felt apply metal eave strips and gravel stops at all edges of the roof as specified in paragraph 6, Section 11, Sheet Metal Work.

6. Coat the entire surface uniformly with hot pitch, using not less than 25 lb. per 100 sq. ft.

7. Over the entire surface lay three layers of tarred rag felt, lapping each sheet of each layer 22 inches over the preceding sheet for 32-inch wide felt or 25 inches for 36-inch wide felt, end laps not less than 6 inches. Hot pitch shall be mopped the full 22 inches or 25 inches respectively on each sheet, using not less than 25 lb. of pitch per 100 sq. ft. between succeeding layers. These layers shall be cut off at vertical surfaces. If roof decks are of gypsum, in addition to the above, the upper edge of each coures of the third layer of felt shall be nailed to the roof deck with galvanized nails driven through tin or zinc caps.

8. Flashings shall be installed at all intersections of the roof with vertical surfaces and the plans will show whether sheet metal or felt flashings shall be used.

Where metal flashings are called for they shall be furnished and installed in accordance with paragraph 4, Section 11, Sheet Metal Work and, in addition, the felt and pitch reinforcement shall be installed as follows:

After all plies of roofing have been laid and before application of the slag or gravel surface, the contractor shall set in separately at the angle of the roof deck and the vertical surface, 3 plies of 14 lb. tarred felt, cemented together with coal-tar pitch. These plies shall extend out on the roof deck at least 4 inches and up the vertical surface 6 inches. The last ply shall be coated with coal-tar pitch and then the metal base and counter flashings installed as specified in Section 11. The flange of the base flashing on the roof shall be coated with hot pitch into which shall be bedded a 4-inch strip of felt centered over the nailing course. This strip shall be coated with hot pitch into which shall be bedded a second strip of felt 6 inches wide completely covering the first.

Where felt flashings are called for, they shall consist of 3 layers of 14 lb. asphalt felt and a cap flashing of 85-lb. slate surfaced roll roofing.

The felt strips shall be cemented to the roof and vertical surfaces and to each other with an approved roofing cement reinforced with mineral fiber. The first strip of felt shall extend 6 inches up the vertical surface and 4 inches out on the roof, the second 8 inches up the wall and 5 inches out on the roof, and the third 10 inches up the wall and 6 inches out on the roof. Felt strips shall not exceed 10 ft. in length and shall be lapped at least one inch at all joints and the joints broken. The cap flashing of mineral surfaced roofing shall extend at least 4 inches in masonry walls and down to the roof deck and shall be cemented to the base flashing with plastic roofing cement.

9. Coat the entire roof surface with hot pitch poured from a dipper, using not less than 75 lb. of pitch per 100 sq. ft. and into this, while hot, embed not less than 400 lb. of dry gravel (or 300 lb. of dry slag). In cold weather the gravel or slag shall be heated before being applied.

Type B–1

Asphalt Rag Felt, Asphalt and Gravel (or Slag) Over Wood or Pre-Cast Units

1. This type of roofing shall be limited to use on wood or pre-cast gypsum roofs having a slope not greater than 4 inches per foot and on pre-cast concrete roofs having a slope not greater than 2 inches per foot.

2. This type of roofing shall be composed of 5 layers of not less than 14 lb. asphalt saturated rag felt, a minimum of 150 lb. of asphalt per 100 sq. ft. and coated with gravel or slag.

3. If on wood, lay one thickness of rosin-sized building paper or impregnated felt weighing not less than 5 lb. per 108 sq. ft., lapping the sheets at least one inch; if on pre-cast units this shall be omitted.

4. Over the entire surface lay two layers of asphalt saturated rag felt, weighing not less than 14 lb. per 108 sq. ft. per layer, lapping each sheet of each layer 17 inches over the preceding sheet for 32-inch wide felt or 19 inches for 36-inch wide felt, end laps not less than 4 inches. Sheets shall be nailed as often as necessary to hold them in place until the remaining felt is laid. These layers shall be turned up against vertical surfaces not less than 6 inches and securely fastened.

5. Over the two layers of 14 lb. felt apply metal eave strips and gravel stops at all edges of the roof as specified in paragraph 6, Section 11, Sheet Metal Work.

6. Coat the entire surface uniformly with hot asphalt, using not less than 25 lb. per 100 sq. ft.

7. Over the entire surface lay three layers of asphalt saturated rag felt, lapping each sheet of each layer 22 inches over the preceding sheet for 32-inch wide felt or 25 inches for 36-inch wide felt, end laps not less than 6 inches. Hot asphalt shall be mopped the full 22 inches, or 25 inches respectively on each sheet, so that in no place will felt touch felt, using not less than 25 lb. of asphalt per 100 sq. ft. between successive layers.

Any nailing necessary shall be done in such manner that all nails will be covered by not less than two layers of felt. Nails shall be galvanized and shall be driven through tin or zinc caps. These layers shall be cut off at vertical surfaces.

8. Flashings shall be installed at all intersections of the roof with vertical surfaces and the plans shall show whether sheet metal or felt flashings shall be used.

Where metal flashings are called for they shall be furnished and installed in accordance with paragraph 4, Section 11, Sheet Metal Work and, in addition, the felt and asphalt reinforcement shall be installed as follows:

After all plies of roofing have been laid and before application of the slag or gravel surface, the contractor shall set in separately at the angle of the roof deck and the vertical surface, 3 plies of 14 lb. asphalt felt, cemented together with hot asphalt. These plies shall extend out on the roof deck at least 4 inches and up the vertical surface 6 inches. The last ply shall be coated with hot asphalt and then the metal base and counter flashings installed as specified in Section 11. The flange of the base flashing on the roof shall be coated with hot asphalt into which shall be bedded a 4-inch strip of asphalt felt centered over the nailing course. This strip shall be coated with hot asphalt into which shall be bedded a second strip of felt 6 inches wide completely covering the first.

Where felt flashings are called for, they shall consist of 3 layers of 14-lb. asphalt felt and a cap flashing of 85-lb. slate surfaced roll roofing.

The felt strips shall be cemented to the roof and vertical surfaces and to each other with an approved plastic roofing cement reinforced with mineral fiber. The first strip of felt shall extend 6 inches up the vertical surface and 4 inches out on the roof, the second 8 inches up the wall and 8 inches out on the roof, and the third 10 inches up the wall and 6 inches out on the roof. Felt strips shall not exceed 10 ft. in length and shall be lapped at least one inch at all joints and the joints broken. The cap flashing of mineral surfaced roofing shall extend at least 4 inches in masonry walls and down to the roof deck and shall be cemented to the base flashing with plastic roofing cement.

9. Coat the entire roof surface with hot asphalt poured from a dipper, using not less than 75 lb. per 100 sq. ft. into which, while hot, embed not less than 400 lb. of dry gravel (or 300 lb. of dry slag). In cold weather the gravel or slag shall be heated before being applied.

Type B–2

Asphalt Rag Felt, Asphalt and Gravel (or Slag) Over Homogeneous Roofs Cast in Place

1. This type of roofing shall be limited to use on roof decks having a slope not greater than 4 inches per foot.

2. This type of roofing shall be composed of one coat of asphalt primer, five layers of not less than 14 lb. asphalt saturated rag felt, a minimum of 205 lb. of asphalt per 100 sq. ft., and coated with gravel or slag.

3. The entire surface, if of concrete, shall be coated uniformly with asphalt primer, using not less than 10 lb. per 100 sq. ft. and allowed to dry.

(If of gypsum, the surface shall be given two such coats.) Upon this there shall be applied a uniform coat of hot asphalt, using not less than 30 lb. per 100 sq. ft.

4. Over this lay two layers of asphalt saturated rag felt, weighing not less than 14 lb. per 108 sq. ft. per layer, lapping each sheet of each layer 17 inches over the preceding sheet for 32-inch wide felt or 19 inches for 36-inch wide felt, end laps not less than 4 inches and securely fastened. Hot asphalt shall be mopped the full 17 inches or 19 inches respectively on each sheet so that in no place will felt touch felt, using not less than 25 lb. of asphalt per 100 sq. ft. between successive layers. These layers shall be turned up against vertical surfaces not less than 6 inches and securely fastened.

5. Over the two layers of 14 lb. felt apply metal eave strips and gravel stops at all edges of the roof as specified in paragraph 6, Section 11, Sheet Metal Work.

6. Coat the entire surface uniformly with hot asphalt, using not less than 25 lb. of asphalt per 100 sq. ft. of roof surface.

7. Over the entire surface lay three layers of asphalt saturated rag felt, lapping each sheet of each layer 22 inches over the preceding sheet for 32-inch wide felt or 25 inches for 36-inch wide felt, end laps not less than 6 inches. Hot asphalt shall be mopped the full 22 inches or 25 inches respectively on each sheet, so that in no place will felt touch felt, using not less than 25 lb. of asphalt per 100 sq. ft. between successive layers. These layers shall be cut off at vertical surfaces.

If roof decks are of gypsum, in addition to the above, the upper edge of each course of the third layer of felt shall be nailed to the roof deck with galvanized nails driven through tin or zinc caps.

8. Flashings shall be installed at all intersections of the roof with vertical surfaces and the plans will show whether sheet metal or felt flashings shall be used.

Where metal flashings are called for they shall be furnished and installed in accordance with paragraph 4, Section 11, Sheet Metal Work and, in addition, the felt and pitch reinforcement shall be installed as follows:

After all plies of roofing have been laid and before application of the slag or gravel surface, the contractor shall set in separately at the angle of the roof deck and the vertical surface, 3 plies of 14-lb. asphalt felt, cemented together with hot asphalt. These plies shall extend out on the roof deck at least 4 inches and up the vertical surface 6 inches. The last ply shall be coated with hot asphalt and then the metal base and counter flashings installed as specified in Section 11. The flange of the base flashing on the roof shall be coated with hot asphalt into which shall be bedded a 4-inch strip of felt centered over the nailing course. This strip shall be coated with hot asphalt into which shall be bedded a second strip of felt 6 inches wide completely covering the first.

Where felt flashings are called for, they shall consist of 3 layers of 14-lb. asphalt felt and a cap flashing of 35-lb. slate surfaced roll roofing.

The felt strips shall be cemented to the roof and vertical surfaces and to each other with an approved plastic roofing cement reinforced with mineral fiber. The first strip of felt shall extend 6 inches up the vertical surface and 4 inches out on the roof, the second 8 inches up the wall and 5 inches out on the roof, and the third 10 inches up the wall and 6 inches out on the roof. Felt strips shall not exceed 10 ft. in length and shall be lapped at least one inch at all joints and the joints broken. The cap flashing of mineral surfaced roofing shall extend at least 4 inches in masonry walls and down to the roof deck and shall be cemented to the base flashing with plastic roofing cement.

9. Coat the entire surface uniformly with hot asphalt poured from a dipper, using not less than 75 lb. of asphalt per 100 sq. ft. into which, while hot, embed not less than 400 lb. of dry gravel (or 300 lb. of dry slag). In cold weather the gravel or slag shall be heated before being applied.

Type C–1 (Class 2)

Asphalt Impregnated Asbestos Felt and Asphalt (Smooth Surface) Over Wood or Pre-Cast Units

1. This type of roofing shall be limited to use on roof decks having a slope not greater than 6 inches per foot for wood or pre-cast gypsum, and to slopes not greater than 3 inches per foot for pre-cast concrete, unless provision is made in the pre-cast concrete units for nailing.

2. This type of roofing shall be composed of one layer approximately 60 lb. and two layers not less than 14 lb. asphalt impregnated asbestos felt and a minimum of 85 lb. of asphalt per 100 sq. ft.

3. Lay sheets of asphalt impregnated asbestos felt weighing approximately 60 lb. per 108 sq. ft. directly over the sheathing. Lap the joints 2 inches and seal them with asphalt. Nail these sheets along the lap with barbed nails driven through tin caps, spaced 6 inches apart, and in parallel lines approximately 10 inches apart and approximately 10 inches from the laps, these nails to be spaced 18 inches apart and staggered. This 60-lb. felt shall be laid parallel to pitch of roof and turned up 6 inches above the roof deck at all vertical surfaces, but not cemented to vertical surfaces.

4. Over the 60-lb. felt apply metal eave strips at all edges of the roof as specified in paragraph 6, Section 11, Sheet Metal Work.

5. Mop the entire surface of the 60-lb. felt with asphalt, heated to flow freely, and, while hot, embed in it sheets of asphalt impregnated asbestos felt, weighing not less than 14 lb. per 108 sq. ft. in two-ply construction; this 14-lb. felt to be run at right angles to the 60-lb. felt, lapped 17 inches for 32-inch wide felt and 19 inches for 36-inch wide felt and turned up 6 inches above the roof deck at all vertical surfaces.

Mop the entire surface between plies with asphalt, heated to flow freely, and roll the felts closely behind the mop so that no missing of asphalt can possibly take place. Approximately 30 lb. of asphalt shall be used per 100 sq. ft. for each mopping between successive layers.

Nail the upper edge of each sheet with barbed nails driven through tin caps, spaced 9 inches apart; the center line of nail heads to be approximately ¾-inch below the upper edge of sheet.

6. Flashings shall be installed at all intersections of the roof with vertical surfaces and the plans will show whether sheet metal or felt flashings shall be used.

Where sheet metal flashings are called for they shall be furnished and installed in accordance with paragraph 4, Section 11, Sheet Metal Work, and shall consist of a metal base and counter flashing installed after the application of the last two plies of felt, but before the final coating of asphalt is applied. The flange of the base flashing on the roof deck shall be coated with asphalt into which shall be bedded a 4-inch strip of 14-lb. asbestos felt centered over the nailing course. This strip shall be coated with hot asphalt into which shall be bedded a second strip of felt 6 inches wide completely covering the first.

Where felt flashings are called for they shall consist of a base flashing of an approved special asbestos flashing material cemented to the vertical surface and the roof deck with hot asphalt, and a cap flashing of the same material turned into masonry walls not less than 4 inches and extending down to the roof deck, cemented to the base flashing, and coated with an approved elastic roofing cement, reinforced with mineral fiber. The base flashing shall extend 4 inches out on the roof deck and not less than 8 inches up the vertical surface and the upper edge shall be nailed to the vertical surface where nailing is possible. Brick or concrete walls shall be coated with asphalt primer before the flashing is installed. The edge of the base flashing on the roof shall be covered with a 4-inch strip of 14-lb. asbestos felt embedded in and coated with hot asphalt. End laps of base and cap flashing shall be 3 inches, with joints broken.

7. When the roof is otherwise complete, cover the entire surface with a mopping of hot asphalt, using not less than 25 lb. of asphalt per 100 sq. ft. of roof surface.

Type C–1 (Class 3)

Asphalt Saturated Rag Felt, Asphalt Impregnated Asbestos Felt and Asphalt (Smooth Surface) Over Wood or Pre-Cast Units

1. This type of roofing shall be limited to roof decks having a slope not greater than 6 inches per foot for wood or pre-cast gypsum, and to slopes not greater than 3 inches per foot for pre-cast concrete, unless provision is made in the concrete for nailing.

2. This type of roofing shall be composed of one layer approximately 30 lb. asphalt rag felt, two layers approximately 14 lb. asphalt impregnated asbestos felt, and a minimum of 85 lb. asphalt per 100 sq. ft.

3. Lay sheets of asphalt saturated rag felt, weighing approximately 30 lb. per 108 sq. ft., directly over the sheathing. Lap the joints 2 inches and seal them with asphalt. Nail these sheets along the lap with barbed nails driven through tin caps, spaced 6 inches apart, and in parallel lines approximately 10 inches apart and approximately 10 inches from the laps; these nails to be spaced 18 inches apart and staggered. This 30-lb. felt shall be laid parallel to pitch of roof and turned up 6 inches above roof deck at all vertical surfaces, but not cemented to vertical surfaces.

4. Over the 30 lb. rag felt apply metal eave strips at edges of the roof as specified in paragraph 6, Section 11, Sheet Metal Work.

5. Mop the entire surface of the 30 lb. felt with the asphalt, heated to flow freely, and while hot, embed into it sheets of asphalt impregnated asbestos felt, weighing not less than 14 lb. per 108 sq. ft. in two-ply construction; this 14 lb. felt to be run at right angles to the 30-lb. felt, lapped 17 inches for 32-inch wide felt and 19 inches for 36-inch wide felt and turned up 6 inches above roof deck at all vertical surfaces.

Mop the entire surface between plies with asphalt heated to flow freely, and roll the felts closely behind the mop so that no missing of asphalt can possibly take place. Approximately 30 lb. of asphalt shall be used per square for each mopping.

Nail the upper edge of each sheet with the barbed nails, driven through tin caps spaced 9 inches apart; the center line of nail heads to be approximately ¾ inch below back edge of sheet.

6. Flashings shall be installed at all intersections of the roof with vertical surfaces, and the plans will show whether sheet metal or felt flashings shall be used.

Where sheet metal flashings are called for, they shall be furnished and installed in accordance with paragraph 4, Section 11, Sheet Metal Work, and shall consist of a metal base and counter flashing, installed after the application of the last two plies of felt but before the final coating of asphalt is applied. The flange of the base flashing on the roof deck shall be coated with hot asphalt, into which shall be bedded a 4-inch strip of 14-lb. asbestos felt, centered over the nailing course. This strip shall be coated with hot asphalt into which shall be bedded a second strip of felt, 6 inches wide completely covering the first.

Where felt flashings are called for they shall consist of a base flashing of an approved special asbestos flashing material, cemented to the vertical surface and the roof deck with hot asphalt, and a cap flashing of the same material turned into masonry walls not less than 4 inches and extending down to the roof deck, and cemented to the base flashing, and coated with an approved elastic roofing cement reinforced with mineral fiber. The base flashing shall extend 4 inches out on the roof deck and not less than 8 inches up the vertical surface and the upper edge shall be nailed to the vertical surface where nailing is possible. Brick or concrete walls shall be coated with asphalt primer before the flashing is installed. The edge of the base flashing on the roof shall be covered with a 4-inch strip of 14-lb. asbestos felt embedded in and coated with hot asphalt. End laps of base and cap flashing shall be 3 inches, with joints broken.

7. When the roof is otherwise complete, cover the entire surface with a mopping of asphalt, using not less than 25 lb. of asphalt per 100 sq. ft. of roof surface.

Type C–2 (Class 2)

Asphalt Impregnated Asbestos Felt and Asphalt (Smooth Surface) Over Homogeneous Roofs Cast in Place

1. This type of roofing shall be limited to use on roof decks having a slope not greater than 6 inches per foot for gypsum or other surfaces that will permit nailing and to slopes not greater than 3 inches per foot for concrete, unless provision is made in the concrete for nailing. Provision for expansion shall be made in covering over expansion joints in concrete slabs.

2. This type of roofing shall be composed of one coat asphalt primer, one coat asphalt over primer, one layer, approximately 60 lb., and two layers approximately 14 lb. asphalt impregnated asbestos felt and a minimum of 115 lb. asphalt per 100 sq. ft., not including primer.

3. Coat the concrete or gypsum with cold asphalt primer, using approximately one gallon over concrete and one to two gallons over gypsum per 100 sq. ft. of roof surface to provide a proper bond between roof deck and asphalt. Allow the primer to dry.

4. Mop the entire surface thus primed with asphalt, using approximately 30 lb. per 100 sq. ft., heated to flow freely, and while the cement is hot embed into it sheets of asphalt impregnated asbestos felt, weighing approximately 60 lb. per 108 sq. ft. Lap the joints 2 inches and seal them with hot asphalt. The 60 lb. felt shall be laid parallel to pitch of roof and turned up 6 inches above roof deck on all vertical surfaces.

5. Over the 60-lb. felt apply metal eave strips at all edges of the roof as specified in paragraph 6, Section 11, Sheet Metal Work.

6. Mop the entire surface of the 60-lb. felt with hot asphalt, and while hot embed into it sheets of asphalt impregnated asbestos felt, weighing not less than 14 lb. per 108 sq. ft. in two-ply construction; this 14 lb. felt to be run at right angles to the 60 lb. felt, lapped 17 inches for 32-inch wide felt and 19 inches for 36-inch wide felt and turned up 6 inches above roof deck at all vertical surfaces.

Mop the entire surface between plies with asphalt, heated to flow freely, and roll the felts closely behind the mop so that no missing of asphalt can possibly take place. Approximately 30 lb. of asphalt shall be used per square for each mopping.

7. On gypsum and other types of roof decks that permit of nailing, the back edges of all felts shall be securely nailed to roof slab with cut nails driven through tin caps in addition to mopping.

8. Flashings shall be installed at all intersections of the roof with vertical surfaces, and the plans will show whether sheet metal or felt flashings shall be used.

Where sheet metal flashings are called for, they shall be furnished and installed in accordance with paragraph 4, Section 11, Sheet Metal Work, and shall consist of a metal base and counter flashing, installed after the application of the last two plies of felt but before the final coating of asphalt is applied. The flange of the base flashing on the roof deck shall be coated with hot asphalt, into which shall be bedded a 4-inch strip of 14 lb. asbestos felt, centered over the nailing course. This strip shall be coated with hot asphalt into which shall be bedded a second strip of felt, 6 inches wide completely covering the first.

Where felt flashings are called for they shall consist of a base flashing of an approved special asbestos flashing material, cemented to the vertical surface and the roof deck with hot asphalt, and a cap flashing of the same material turned into masonry walls not less than 4 inches and extending down to the roof deck, and cemented to the base flashing, and coated with an approved elastic roofing cement reinforced with mineral fiber. The base flashing shall extend 4 inches out on the roof deck and not less than 8 inches up the vertical surfaces, and the upper edge shall be nailed to the vertical surface, where nailing is possible. Brick or concrete walls shall be coated with asphalt primer before the flashing is installed. The edge of the base flashing on the roof shall be covered with a 4-inch strip of 14-lb. asbestos felt, embedded in and coated with hot asphalt. End laps of base and cap flashing shall be 3 inches with joints broken.

9. When the roof is otherwise complete, cover the entire surface with a mopping of hot asphalt, using not less than 25 lb. of asphalt per 100 sq. ft. of roof surface.

Type C–2 (Class 3)

Asphalt Saturated Rag Felt, Asphalt Impregnated Asbestos Felt and Asphalt (Smooth Surface) Over Homogeneous Units Cast in Place

1. This type of roofing shall be limited to use on roof decks having a slope not greater than 6 inches per foot for gypsum or other surfaces that will permit nailing and to slopes not greater than 3 inches per foot for concrete, unless provision is made in the concrete for nailing. Provision for expansion shall be made in covering over expansion joints in concrete slabs.

2. This type of roofing shall be composed of one coat of asphalt primer, one coat asphalt over primer, one layer approximately 30 lb. asphalt rag felt and two layers approximately 14 lb. asphalt impregnated asbestos felt, and a minimum of 115 lb. asphalt per 100 sq. ft., not including primer.

3. Coat the concrete or gypsum with asphalt primer, using approximately 1 gallon over concrete and not less than 1 gallon over gypsum per 100 sq. ft. to provide a proper bond between roof deck and asphalt. Allow the primer to dry.

4. Mop the entire surface thus primed with asphalt, heated to flow freely, and while hot, embed in it sheets of asphalt rag felt, weighing approximately 30 lb. per 108 sq. ft. Lap the joints 2 inches and seal them with hot asphalt. This 30-lb. felt shall be laid parallel to pitch of roof and turned up 6 inches above roof deck at all vertical surfaces.

5. Over the 30-lb. felt apply metal eave strips at all edges of the roof as specified in paragraph 6, Section 11, Sheet Metal Work.

6. Mop the entire surface of the 30-lb. felt with hot asphalt, and while hot, embed into it sheets of asphalt impregnated asbestos felt, weighing not less than 14 lb. per 108 sq. ft. in two-ply construction; this 14 lb. felt to be run at right angles to the 30-lb. felt, lapped 17 inches for 32-inch wide felt and 19 inches for 36-inch wide felt and turned up 6 inches above roof deck at vertical surfaces.

Mop the entire surface between plies with the asphalt, heated to flow freely, and roll the felts closely behind the mop so that no missing of asphalt can possibly take place. Approximately 30 lb. of asphalt shall be used per 100 sq. ft. for each mopping.

7. On gypsum and other types of roof decks that permit of nailing, the back edges of all felt shall be securely nailed to roof slab with cut nails driven through tin caps in addition to mopping.

8. Flashings shall be installed at all intersections of the roof with vertical surfaces, and the plans will show whether sheet metal or felt flashings shall be used.

Where sheet metal flashings are called for, they shall be furnished and installed in accordance with paragraph 4, Section 11, Sheet Metal Work, and shall consist of a metal base and counter flashing, installed after the application of the last two plates of felt but before the final coating of asphalt is applied. The flange of the base flashing on the roof deck shall be coated with hot asphalt, into which shall be bedded a 4-inch strip of 14 lb. asbestos felt, centered over the nailing course. This strip shall be coated with hot asphalt into which shall be bedded a second strip of felt, 6 inches wide completely covering the first.

Where felt flashings are called for they shall consist of a base flashing of an approved special asbestos flashing material, cemented to the vertical surface and the roof deck with hot asphalt, and a cap flashing of the same material turned into masonry walls not less than 4 inches and extending down to the roof deck, and cemented to the base flashing, and coated with an approved elastic roofing cement reinforced with mineral fiber. The base flashing shall extend 4 inches out on the roof deck and not less than 8 inches up the vertical surfaces, and the upper edge shall be nailed to the vertical surface, where nailing is possible. Brick or concrete walls shall be coated with asphalt primer before the flashing is installed. The edge of the base flashing on the roof shall be covered with a 4-inch strip of 14 lb. asbestos felt, embedded in and coated with hot asphalt. End laps of base and cap flashing shall be 3 inches, with joints broken.

9. When the roof is otherwise complete, cover the entire surface with a mopping of hot asphalt, using not less than 25 lb. of asphalt per 100 sq. ft. of roof surface.

4. Guarantee

The contractor shall furnish an unqualified guarantee, with good and sufficient bond covering the maintenance of the entire roof and all flashing in a watertight condition for a period of years from date of completion and acceptance of the entire roof.

5. General Conditions

All materials entering into the work and all methods used by the contractor shall be subject to the approval of the Engineer and no part of the work will be considered as finally accepted until all of the work is completed and accepted.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this section of the specification.

Appendix B

(2) PREPARATION OF SPECIFICATIONS FOR RAILWAY BUILDINGS

F. R. Judd, Chairman, Sub-Committee; J. N. Grim, E. L. Haberle, L. C. Hinsch, A. C. Irwin, O. M. Rognan.

The Committee submits for publication in the Manual, Specifications for Electrically Operated Freight or Baggage Elevators, previously published in the Proceedings as part of Appendix A, Section 29, pages 682 to 688, both inclusive, of Bulletin 354, Vol. 34, Proceedings 1933.

The following specifications are submitted at this time for publication in the Proceedings as information for criticism:

Section 30–D, Steel Chimneys—Welded.
Section 30–E, Genuine Wrought Iron Chimneys.
Section 10–D, Built-up Roofing, Type C–1 (Class 1).
Asphalt Impregnated Asbestos Felt and Asphalt (Smooth Surface) over Wood or Pre-cast Units.
Built-up Roofing, Type C–2 (Class 1).
Asphalt Impregnated Asbestos Felt and Asphalt (Smooth Surface) over Homogeneous Roofs Cast-in-place.
Section 31–A, Wood Screens.
Section 31–B, Metal Screens.

The Committee now has in course of preparation a specification for Genuine Wrought Iron Chimneys—Welded, and has under consideration the preparation of a specification for Reinforced Brick Chimneys. The Committee also has under consideration the revising of specifications for Asphalt Impregnated Felt Roofing over Wood or Pre-cast Gypsum and over Concrete or Poured Gypsum, Section 10–D, Types D–1 and D–2, published in Bulletin 323, January, 1930. The revisions are necessary in order that these specifications might agree in form and arrangement with those referred to in the foregoing Appendix A.

SPECIFICATIONS FOR BUILDINGS FOR RAILWAY PURPOSES

Section 30–D

STEEL CHIMNEYS—WELDED

1. General

The contractor shall completely design and shall furnish all labor, material, tools and equipment, and construct a steel chimney of the height and diameter shown on drawings and as specified. The chimney shall be either self-supporting, guyed or stayed as shown on drawings and as specified.

2. Design

See Section 30–A, Steel Chimneys. Article 2.

3. Unit Stresses

The chimney and its foundations shall be so designed that the following unit stresses shall not be exceeded:

The stresses in welds shall be considered on net sections through the throat of the weld, excluding any reinforcement.

Fillet welds placed transverse to the direction of stress shall be considered as under shear.

Shear on net section through throat of weld	11,300 lb. per sq. in.
Tension on net section through throat of weld	15,000 " " " "
Compression on net section through throat of weld	15,000 " " " "
Tension in steel plates (net section)	12,000 " " " "
Compression in steel plates (gross section)	10,000 " " " "
Extreme fiber in bending	16,000 " " " "
Tension in steel anchor bolts (net section)	16,000 " " " "
Tension in steel stays (net section)	16,000 " " " "
Shear in steel plates	9,000 " " " "
Bearing on steel plates	18,000 " " " "
Compression in steel stays	18,000—60 l/r lb. per sq. in.
Tension in steel guys	⅕ ultimate strength
Tension in reinforcing steel (intermediate grade)	18,000 lb. per sq. in.
Bond in reinforcing steel (deformed bars)	100 lb. " " "
Bond in reinforcing steel (plain bars)	80 lb. " " "
2000 pound concrete, compression	400 lb. " " "
2000 pound concrete, shear	60 lb. " " "

Ratio moduli elasticity, steel and concrete = 15
l = length of member, in inches.
r = least radius of gyration of member, in inches.
Bearing on soil, determined by local conditions.
Pile loading, determined by local conditions.

Working Stresses of Standard Fillet Welds, in Shear

¼"	fillet—2000	lb.	per	linear	inch.
5/16"	" —2500	"	"	"	"
⅜"	" —3000	"	"	"	"
7/16"	" —3500	"	"	"	"
½"	" —4000	"	"	"	"
9/16"	" —4500	"	"	"	"
⅝"	" —5000	"	"	"	"

4. Foundation

See Section 30–A, Steel Chimneys. Article 4.

5. Excavation

See Section 30–A, Steel Chimneys. Article 5.

6. Concrete

See Section 30–A, Steel Chimneys. Article 6.

7. Steel

See Section 30–A, Steel Chimneys. Article 7.

8. Welding

If the chimney is to be assembled before it is erected, it shall be temporarily braced or designed to properly withstand all stresses that may occur while it is being handled and during the process of erection.

Finished chimneys shall be true to line, free from twists, bends and open joints, and shall be gas tight.

The Contractor designing or supervising the chimney shall be experienced and skilled in such work.

Contractors shall satisfy the Engineer that they can meet the qualification tests and furnish satisfactory materials and equipment to be used on the proposed work.

The weld metal shall be sound throughout and be free from excessive oxides, slag inclusion and gas pockets.

The weld metal shall penetrate into the root of the joint.

The weld metal shall be thoroughly fused with the base metal along all surfaces and edges of union. Uniform fusion with base metals of unequal thickness shall be obtained by playing the arc or flame a proportionately longer time upon the thicker material.

The surface of welds shall be reasonably smooth and uniform in contour. The depth of the crater at the terminus of weld shall not be less than $\frac{1}{16}$-inch.

The weld metal along the toe of the weld shall not overlap the base metal surface, but shall form an intimate contact therewith.

The base metal along the toe of the weld shall not be reduced in thickness by the welding operation.

Adequate platform or scaffolding shall be provided to permit favorable welding conditions and to insure the safety of the welders.

The operator, while welding, shall be protected from the rays by suitable equipment provided for the purpose.

The arrangement of the joints to be welded shall be such as to enable the welder to have an unobstructed view of the surfaces to be welded during the welding operation.

When tack welds are located in the path of designed welds, they shall, during the welding operation, be either melted out or fused in with the final weld.

Proper fusion, penetration and soundness of weld shall be secured by using as short an arc as can be maintained for each form of weld.

In gas welding, unless otherwise specified, always use a neutral flame.

Surfaces to be welded shall be free from loose mill scale, rust, paint or other foreign matter. A thin coat of linseed oil or equivalent, over the surfaces to be welded, need not be removed. This provision applies both in the case of new structures and where new material is to be welded to material in an existing structure.

In assembling and during welding, the component parts of a built up member shall be held by sufficient clamps or other adequate means to hold the parts in proper relation for welding.

For structures over 30 (thirty) feet in height, erection bolts or equivalent means shall be employed for temporarily supporting the members.

Proper alinement of the various members shall be made before connections are welded.

All electrodes, welding wire and welding rods shall be of a good, approved grade, such as recommended by the American Welding Society in its Code for Fusion Welding and Gas Cutting in Building Construction, which in the hands of an experienced welder shows good weldability in flat, vertical and overhead positions.

Plates forming the shell of the chimney shall be slightly conical so that the upper ring will always fit inside of the section below. Vertical seams shall be so located as to break joints. Lap joints shall be used for circumferential seams and butt joints shall be used for vertical seams.

The circumferential laps shall have a full strength fillet weld on the outside. A caulk weld bead shall be placed on the inside lap to insure gas-tightness.

One or both edges of base metal parts, ¼-inch or more in thickness, transmitting stress by means of butt welds shall be beveled. For single and double vee joints, the bevel of each part shall be not less than thirty degrees (30°), thus forming an open space with an angle of not less than sixty degrees (60°). For single and double bevel joints, the bevel shall be not less than forty-five degrees (45°). Before welding, the root edge or face of one part shall be separated from the root edge or face of the other part.

All butt welds shall be reinforced by depositing additional metal on the weld to a height extending beyond the surface of the thinnest part joined. The height of said reinforcement shall be not less than the following percentages of the thickness of the thinnest part joined: twenty per cent (20%) for single vee and single bevel butt welds, and twelve and one-half per cent (12½%) on each side for double vee and double bevel butt welds.

9. **Details of Work**

See Section 30–A, Steel Chimneys. (Paragraphs 1, 5, 6 and 7 only of Article 8)

10. **Accessories**

See Section 30–A, Steel Chimneys. Article 9.

11. **Breaching Opening**

See Section 30–A, Steel Chimneys. Article 10.

12. **Cleanout Door**

See Section 30–A, Steel Chimneys. Article 11.

13. **Painter's Collar**

See Section 30–A, Steel Chimneys. Article 12.

14. **Grounding for Lightning Protection**

See Section 30–A, Steel Chimneys. Article 13.

15. **Chimney Lining**

See Section 30–A, Steel Chimneys. Article 14.

16. **Ladder**

See Section 30–A, Steel Chimneys. Article 15.

17. **Draft Gage**

See Section 30–A, Steel Chimneys. Article 16.

18. **Pyrometer**

See Section 30–A, Steel Chimneys. Article 17.

19. **Painting**

All steel shall be cleaned of dirt, rust and scale and all surfaces, except those which would affect the successful welding of the members, shall be given a shop coat of red lead and linseed oil. After erection, the chimney shall receive two (2) coats of an approved paint.

20. **Guarantee**

See Section 30–A, Steel Chimneys. Article 19.

21. **General Conditions**

All material entering into the work and all methods used by the Contractor shall be subject to the approval of the engineer, and no part of the work will be considered as finally accepted until all of the work is completed and accepted.

The General Conditions in Section 1 of these specifications shall apply with equal force in this section of the specifications.

Section 30–E

GENUINE WROUGHT IRON CHIMNEYS

1. **General**

The contractor shall completely design and shall furnish all labor, material, tools and equipment, and construct a genuine wrought iron chimney of the height and diameter shown on drawings and as specified. The chimney shall be either self-supporting, guyed or stayed, as shown on drawings and as specified.

2. Design

See Section 30–A, Steel Chimneys. Article 2.

3. Unit Stresses

The chimney and its foundations shall be so designed that the following unit stresses shall not be exceeded:

Tension in genuine wrought iron plates	12,000 lb. per sq. in. net section
Compression in genuine wrought iron plates	10,000 lb. per sq. in. gross section
Shear in genuine wrought iron rivets and plates	9,000 lb. per sq. in.
Bearing on genuine wrought iron rivets and plates	18,000 lb. per sq. in.
Extreme fiber in bending	12,000 lb. per sq. in.
Tension in genuine wrought iron anchor bolts	14,000 lb. per sq. in. net section
Tension in steel guys	⅕ ultimate strength
Tension in genuine wrought iron stays	14,000 lb. per sq. in. net section
Compression in genuine wrought iron stays	18,000—60 l/r per sq. in. (not to exceed 14,000 lb. per sq. in.)
2000 pound concrete, compression	400 lb. per sq. in.
2000 pound concrete, shear	60 lb. per sq. in.
Reinforcing steel, tension (intermediate grade)	18,000 lb. per sq. in.
Reinforcing steel, bond, deformed bars	100 lb. per sq. in.
Reinforcing steel, bond, plain bars	80 lb. per sq. in.

Ratio moduli elasticity steel and concrete = 15
l = length of member in inches.
r = least radius of gyration of member in inches.
Bearing on soil, determined by local conditions.
Pile loading, determined by local conditions.

4. Foundation

See Section 30–A, Steel Chimneys. Article 4.

5. Excavation

See Section 30–A, Steel Chimneys. Article 5.

6. Concrete

See Section 30–A, Steel Chimneys. Article 6.

7. Materials and Workmanship

All plates shall be of genuine wrought iron in accordance with the American Society for Testing Materials Specification A–42 and subsequent revisions thereof.

All anchor bolts, bars and structural shapes shall be of genuine wrought iron in accordance with the American Society for Testing Materials Specification A–41 and subsequent revisions thereof, which is the standard specification for refined wrought iron bars.

All rivets shall be made from genuine wrought iron, in accordance with the current specifications of the American Society for Testing Materials.

Finished chimneys shall be true to line, free from twists, bends and open joints, and shall be gas tight.

All workmanship shall comply with the standard specification for structural steel and iron, Section 12–A of these specifications, unless otherwise specified.

8. Details of Iron Work

See Section 30–A, Steel Chimneys. Article 8. Substitute the phrase "genuine wrought iron" for the word "steel".

9. Accessories

See Section 30–A, Steel Chimneys. Article 9.

10. Breeching Opening

See Section 30–A, Steel Chimneys. Article 10.

11. Cleanout Door

See Section 30–A, Steel Chimneys. Article 11. Substitute the phrase "genuine wrought iron" for the word "steel".

12. Painter's Collar

See Section 30–A, Steel Chimneys. Article 12. Substitute the phrase "genuine wrought iron" for the words "structural steel".

13. Grounding for Lightning Protection

See Section 30–A, Steel Chimneys. Article 13.

14. Chimney Lining

See Section 30–A, Steel Chimneys. Article 14.

15. Ladder

See Section 30–A, Steel Chimneys. Article 15. Substitute the phrase "genuine wrought iron" for the word "steel".

16. Draft Gage

See Section 30–A, Steel Chimneys. Article 16.

17. Pyrometer

See Section 30–A, Steel Chimneys. Article 17.

18. Painting

See Section 30–A, Steel Chimneys. Article 18. Substitute the phrase "genuine wrought iron" for the word "steel".

19. Guarantee

See Section 30–A, Steel Chimneys. Article 19.

20. General Conditions

All materials entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer, and no part of the work will be considered as finally accepted until all of the work is completed and accepted.

The General Conditions in Section 1 of these specifications shall apply with equal force to this article of the specification.

Section 10–D

BUILT-UP ROOFING

Type C–1 (Class 1)

Asphalt Impregnated Asbestos Felt and Asphalt (Smooth Surface) Over Wood or Pre-Cast Units

1. This type of roofing shall be limited to roof decks having a slope not greater than 6 inches per foot for wood and pre-cast gypsum and to a slope not greater than 3 inches per foot for pre-cast concrete, unless provision is made in the pre-cast concrete units for nailing.

2. This type of roofing shall be composed of one layer approximately 60 lb., three layers not less than 14 lb. asphalt impregnated asbestos felt and a minimum of 115 lb. of asphalt per 100 sq. ft.

3. Lay sheets of asphalt impregnated asbestos felt weighing approximately 60 lb. per 108 sq. ft. directly over the sheathing. Lap the joints 2 inches and seal them with

asphalt. Nail these sheets along the lap with barbed nails driven through tin caps spaced 6 inches apart and in parallel lines approximately 10 inches apart and approximately 10 inches from the laps, these nails to be spaced 18 inches apart and staggered. This 60 lb. felt shall be laid parallel to the pitch of the roof and turned up 6 inches above roof deck at all vertical surfaces, but not cemented to vertical surfaces.

4. Over the 60 lb. felt, apply metal eave strips at edges of the roof as specified in paragraph 6, Section 11, Sheet Metal Work.

5. Mop the entire surface of the 60 lb. felt with the asphalt, heated to flow freely, and while hot, embed into it sheets of asphalt impregnated asbestos felt, weighing not less than 14 lb. per 108 sq. ft. in three ply construction; this 14 lb. felt to be run at right angles to the 60 lb. felt, lapped 22 inches for 32-inch wide felt and 25 inches for 36-inch wide felt, and turned up 6 inches above roof deck at all vertical surfaces.

Mop the entire surface between plies with asphalt, heated to flow freely, and roll the felts closely behind the mop, so that no missing of asphalt can possibly take place. Approximately 30 lb. of asphalt shall be used per square for each mopping.

Nail the upper edge of each sheet with the barbed nails, driven through tin caps spaced 9 inches apart; the center line of nail heads to be approximately ¾ inch below back edge of sheet.

6. Flashing shall be installed at all intersections of the roof with vertical surfaces and the plans will show whether sheet metal or felt flashings shall be used.

Where sheet metal flashings are called for, they shall be furnished and installed in accordance with paragraph 4, Section 11, Sheet Metal Work, and shall consist of a metal base and counter flashing, installed after the application of the last three plies of felt, but before the final coating of asphalt is applied. The flange of the base flashing on the roof deck shall be coated with hot asphalt, into which shall be bedded a 4-inch strip of 14 lb. asbestos felt, centered over the nailing course. This strip shall be coated with hot asphalt, into which shall be bedded a second strip of felt, 6 inches wide, completely covering the first.

Where felt flashings are called for, they shall consist of a base flashing of an approved special asbestos flashing material, cemented to the vertical surface and the roof deck with hot asphalt, and a cap flashing of the same material turned into masonry walls not less than 4 inches and extending down to the roof deck and cemented to the base flashing and coated with an approved elastic roofing cement, reinforced with mineral fiber. The base flashing shall extend 4 inches out on the roof deck and not less than 8 inches up the vertical surface and the upper edge shall be nailed to the vertical surface where nailing is possible. Brick or concrete walls shall be coated with asphalt primer before the flashing is installed. The edge of the base flashing on the roof shall be covered with a 4 inch strip of 14 lb. asbestos felt, embedded in and coated with hot asphalt. End laps of base and cap flashing shall be 3 inches, with joints broken.

7. When the roof is otherwise complete, cover the entire surface with a mopping of hot asphalt, using not less than 25 lb. of asphalt per 100 sq. ft. of roof surface.

Section 10–D

BUILT-UP ROOFING

Type C–2 (Class 1)

Asphalt Impregnated Asbestos Felt and Asphalt (Smooth Surface) Over Homogeneous Roofs Cast in Place

1. This type of roofing shall be limited to use on roof decks having a slope not greater than 6 inches per foot for gypsum or other surfaces that will permit nailing and to slopes not greater than 3 inches per foot for concrete, unless provision is made in the concrete for nailing. Provision for expansion shall be made in covering over expansion joints in concrete slabs.

2. This type of roofing shall be composed of one coat asphalt primer, one coat asphalt over primer, one layer, approximately 60 lb., and three layers not less than 14 lb. asphalt impregnated asbestos felt and a minimum of 145 lb. asphalt per 100 sq. ft., not including primer.

3. Coat the concrete or gypsum with cold asphalt primer, using approximately one gallon over concrete and one to two gallons over gypsum per 100 sq. ft. of roof surface, to provide a proper bond between roof deck and asphalt. Allow the primer to dry.

4. Mop the entire surface thus primed with asphalt, using approximately 30 lb. per 100 sq. ft., heated to flow freely, and while hot, embed into it sheets of asphalt impregnated asbestos felt, weighing approximately 60 lb. per 108 sq. ft. Lap the joints 2 inches and seal them with hot asphalt. The 60 lb. felt shall be laid parallel to pitch of roof and turned up 6 inches above roof deck on all vertical surfaces.

5. Over the 60 lb. felt apply metal eave strips at all edges of the roof as specified in paragraph 6, Section 11, Sheet Metal Work.

6. Mop the entire surface of the 60 lb. felt with hot asphalt and while hot, embed into it sheets of asphalt impregnated asbestos felt, weighing not less than 14 lb. per 108 sq. ft., in 3 ply construction; this 14 lb. felt to be run at right angles to the 60 lb. felt, lapped 22 inches for 32-inch wide felt and 25 inches for 36-inch wide felt and turned up 6 inches above roof deck at all vertical surfaces.

Mop the entire surface between plies with asphalt, heated to flow freely and roll the felts closely behind the mop, so that no missing of asphalt can possibly take place. Approximately 30 lb. of asphalt shall be used per square for each mopping.

7. On gypsum and other types of roof decks that permit of nailing, the back edges of all felts shall be securely nailed to roof slab with cut nails driven through tin caps in addition to mopping.

8. Flashing shall be installed at all intersections of the roof with vertical surfaces and the plans will show whether sheet metal or felt flashings shall be used.

Where sheet metal flashings are called for, they shall be furnished and installed in accordance with paragraph 4, Section 11, Sheet Metal Work, and shall consist of a metal base and counter flashing, installed after the application of the last three plies of felt, but before the final coating of asphalt is applied. The flange of the base flashing on the roof deck shall be coated with hot asphalt, into which shall be bedded a 4 inch strip of 14 lb. asbestos felt, centered over the nailing course. This strip shall be coated with hot asphalt, into which shall be bedded a second strip of felt, 6 inches wide, completely covering the first.

Where felt flashings are called for, they shall consist of a base flashing of an approved special asbestos flashing material, cemented to the vertical surface and the roof deck with hot asphalt, and a cap flashing of the same material turned into masonry walls not less than 4 inches and extending down to the roof deck and cemented to the base flashing and coated with an approved elastic roofing cement, reinforced with mineral fiber. The base flashing shall extend 4 inches out on the roof deck and not less than 8 inches up the vertical surface and the upper edge shall be nailed to the vertical surface where nailing is possible. Brick or concrete walls shall be coated with asphalt primer before the flashing is installed. The edge of the base flashing on the roof shall be covered with a 4 inch strip of 14 lb. asbestos felt, embedded in and coated with hot asphalt. End laps of base and cap flashing shall be 3 inches, with joints broken.

9. When the roof is otherwise complete, cover the entire surface with a mopping of hot asphalt, using not less than 25 lb. of asphalt per 100 sq. ft. of roof surface.

Section 31–A

WOOD SCREENS

1. General

The contractor shall furnish all labor, material, tools and equipment necessary to furnish and place complete all wood screens for windows, transoms and doors, complete with necessary hardware as herein specified and as shown and implied on the drawings.

2. Woodwork

Window, transom and door screens shall be made of kiln dried genuine White Pine. (See Note 1) Woodwork shall be dressed and sanded to a smooth finish. Corners and joints shall be rigid and substantial. Window screens shall be full length type, (See Note 2) frames shall be 1⅛ in. thick, (See Note 3) stiles and rails of such widths as to match windows, transoms and doors. Suitable screen moulding shall be used to secure wire cloth to frames.

3. Wire Cloth

Wire cloth shall be 16 mesh copper bronze of an approved make. (See Note 4)

4. Hardware

Window and transom screens shall be equipped with approved metal hangers, hook and eyes, or other suitable approved type of fasteners. Screen doors shall be equipped with loose pin butts, screen door check, screen door fastener, pull and plate of an approved make. (See Note 5)

Wire cloth in lower portion of screen doors shall be protected from damage by horizontal ⅝″ round bars of same finish as hardware, placed on both sides of doors, (See Note 6) to each door, spaced (See Note 7) inches on centers.

5. Number Tags

Window, transom and door screens, shall be provided with a duplicate set of non-corrosive metal number tags, one applied to each screen and one to each corresponding opening.

6. Finishing

Woodwork of window, transom and door screens shall be painted in accordance with painting and glazing specification. Copper bronze wire cloth (See Note 4) shall not be painted. (See Note 8)

7. Shop Drawings

When required by the Engineer and before proceeding with this work, the contractor shall submit for approval of the Engineer, shop or detail drawings covering all wood screen work, together with list of finish hardware to be furnished, make of copper bronze wire cloth, etc. (See Note 4)

8. Guarantee

All wood screens shall be guaranteed for the stated period of years given in the contractor's proposal and all or any wood screens shall be replaced by the contractor at his own expense if they prove defective in workmanship, material or operation.

9. General Conditions

All materials entering into the work and all methods used by the contractor shall be subject to the approval of the Engineer and no part of the work will be considered as finally accepted until all the work is completed and accepted.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this section of the specification.

Notes—Wood Screens

(1) Other kinds of woods may be used—change as required for particular work under consideration.

Wood Frames

Other kinds of woods used for screen frames, depending upon locality, use and type of building.

Cypress
Cedars
Douglas Fir
Hemlock
Spruce
Redwood
Yellow Poplar
Southern Pine
Pondosa Pine
Birch
Oaks
Chestnut

Also veneered hardwoods over wood cores of suitable wood.

(2) Type of window screens vary—substitute type desired for particular work under consideration.

TYPE OF SCREENS

Full Screens
Half Screens
Double Vertical Sliding Screens
Single Vertical Sliding Screens
Hinged Screens, Top and Sides
Circular Screens for Pivoted Sash
Double Screens for Pivoted Sash
Adjustable Screens
Horizontal Sliding Screens
Lift-Fold Screens
Pivoted Screens

(3) Thickness may vary—substitute change desired for particular work under consideration.

(4) Different kinds of wire cloth can be used—substitute change desired for particular work under consideration.

WIRE CLOTH

Pure Copper, 99.9 per cent and 99.8 per cent
Monel Metal
Bronze
Copper Bronze 90 per cent
Mono-Bronze
Anaconda Bronze
Black Galvanized
"Ambrac"—Alloys of nickel and copper
Electro-galvanized steel wire (Trade names as, "Alumina", "Gray-Wick", "Opal", "Apex", "Galvanoid")
Hot Galvanized
Galvanized
Painted Black
Black Enamel
Pearl

MESHES

Wire cloth meshes used for screen work—12, 14, 16, 18, 20, 24, 40, 60, 100.

(5) Other finish hardware trimming than specified may be desired. Change if so desired.

(6) State number of bars desired.

(7) State centers for spacing of bars.

(8) Finishing may be different than specified, change if desired.

Section 31–B

METAL SCREENS

1. General

The contractor shall furnish all labor, material, tools and equipment necessary to furnish and place complete all metal screens for windows, transoms and doors, complete with necessary hardware as herein specified and as shown and implied on the drawings.

2. Metal Work

Window, transom and door screens shall be (See Note 1) as made by (See Note 2) or other approved equal.

3. Wire Cloth

Wire cloth shall be 16 mesh (See Note 3) of an approved make.

4. Hardware

Window and transom screens shall be equipped with approved metal hangers and suitable approved type of fasteners. Screen doors shall be equipped with loose pin butts, screen door check, screen door fastener, pull and plate of an approved make. (See Note 4)

Wire cloth in lower portion of screen doors shall be protected from damage by horizontal 5/8" round bars of same finish as hardware, placed on both sides of doors, (See Note 5) to each door, spaced (See Note 6) inches on centers.

5. Number Tags

All removable screens for windows, transoms and doors shall be provided with an approved method of numbering. Each screen and opening shall have a corresponding number or designation.

6. Finishing

Finish of all metal screens shall be (See Note 7).

7. Shop Drawings

When required by the Engineer and before proceeding with this work, the contractor shall submit for approval of the Engineer, shop or detail drawings covering all metal screen work, together with samples of construction, hardware, etc.

8. Guarantee

All metal screens shall be guaranteed for the stated period of years given in the contractor's proposal and all or any metal screens shall be replaced by the contractor at his own expense if they prove defective in workmanship, material or operation.

9. General Conditions

All materials entering into the work and all methods used by the contractor shall be subject to the approval of the Engineer and no part of the work will be considered as finally accepted until all the work is completed and accepted.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this section of the specification.

NOTES—METAL SCREENS

(1) State type of screen to be used for particular work under consideration.

METAL FRAMES

Following are some of the kinds of metal used by various manufacturers of metal screens—

Cold Rolled Steel—Galvanized with pure zinc.
Cold Rolled Bronze.
Enameled Galvanized Steel.
Copper.
Aluminum Alloy.
Aluminum.
Lead Coated Terne Plate Metal.
Monel Metal.
Electro-galvanized Copper Bearing Alloy Coated Metal.

TYPES OF SCREENS

Full Screens.
Half Screens.
Rolling Screens.
Double Vertical Sliding Screens.
Single Vertical Sliding Screens.
Hinged Screens, Top and Sides.
Circular Screens for Pivoted Sash.
Double Screens for Pivoted Sash.
Adjustable Screens.
Horizontal Sliding Screens.
Lift-Fold Screens.
Pivoted Screens.

(2) Give name and address of manufacturer.

(3) Different kinds of wire cloth can be used—state kind desired, change mesh if desired for particular work under consideration.

WIRE CLOTH

Pure Copper, 99.9 per cent and 99.8 per cent
Monel Metal
Bronze
Copper Bronze 90 per cent
Mono-Bronze
Anaconda Bronze
Black Galvanized
"Ambrac"—Alloys of nickel and copper
Electro-galvanized steel wire (Trade name as, "Alumina", "Gray-Wick", "Opal", "Apex", "Galvanoid")
Hot Galvanized
Galvanized
Painted Black
Black Enamel
Pearl

MESHES

Wire cloth meshes used for screen work—12, 14, 16, 18, 20, 24, 40, 60, 100.

(4) Other finish hardware trimming than specified may be desired. Change if so desired.

(5) State number of bars desired.

(6) State centers for spacing of bars.

(7) State finish desired for metal frames.

Appendix C

(3) REMODELING FREIGHT HOUSES FOR ACCOMMODATION OF TRUCK DOOR-TO-DOOR DELIVERY OF FREIGHT

A. C. Copland, Chairman, Sub-Committee; A. L. Becker, R. E. Mohr, E. A. Harrison, G. H. Burnette.

All l.c.l. freight is, to all intents and purposes, a door-to-door delivery, either by individual trucks or trucking companies.

Existing freight houses usually have tracks on one or both sides for the loading or unloading of freight cars. Generally, on one side is the tailboard space, with or without platform, for trucks or other vehicles delivering or receiving freight. The same arrangement should meet the requirements of the door-to-door system, consequently it is unnecessary to remodel existing freight houses materially, if any. All that is involved is a change in responsibility and operation.

Appendix D

(4) BUS TERMINAL BUILDINGS, ISOLATED AND IN CONJUNCTION WITH RAILWAY STATIONS

O. G. Wilbur, Chairman, Sub-Committee; C. L. Wenkenbach, E. W. Niblet, J. W. Orrock, C. D. Horton, F. R. Micheal.

Considerable data has been assembled on this subject and a report is being prepared. It is the recommendation that this subject be continued another year.

Appendix E

(5) APPLICATION OF STAINLESS AND RUST-RESISTING METALS TO BUILDING CONSTRUCTION

J. W. Orrock, Chairman, Sub-Committee; F. B. Doolittle, Hugo Filippi, A. B. Stone, C. D. Horton, E. L. Haberle.

Information on this subject is being assembled but sufficient data for incorporation in a report is not yet available. It is recommended that the subject be continued another year.

Appendix F

(6) VERMIN AND RAT-PROOFING IN BUILDINGS

A. H. Morrill, Chairman, Sub-Committee; Hugo Filippi, A. C. Irwin, W. T. Dorrance, L. C. Hinsch, J. A. Stocker.

The Committee reports progress but is not sufficiently prepared to present a tentative report. It is recommended that the subject be continued another year.

Appendix G

(7) RELATIVE MERITS OF WOOD AND FIREPROOF ROOF STRUCTURES, WHICH INCLUDES WOOD, HOLLOW TILE FIRE-PROOFING, CONCRETE AND CEMENT TILE, ETC.

A. T. Upson, Chairman, Sub-Committee; O. M. Rognan, F. B. Doolittle, C. L. Wenkenbach, J. N. Grim, A. C. Irwin, E. Christiansen.

I—Wood Decks

A Wood Sheathing, 2 in. and Thinner, on Closely Spaced Wood Rafters.—This construction is relatively inexpensive. It is combustible, and difficult to protect with sprinklers. It lends itself readily to various types of roof coverings. It is adaptable to small roofs of irregular shapes. It is a fair insulator of heat.

B Wood Decking, 2½ in. and Thicker, on Wood Beams or Purlins of Not Less Than 6 in. Nominal Minimum Dimension.—This construction is slow burning and readily protected with sprinklers. It is a good insulator of heat. It can be used with any type of roof covering.

C Wood Decking, 2½ in. and Thicker, on Steel Beams or Purlins.—The wood decking is slow burning, but the combination is of low fire-resisting value because of warping of the steel beams in a fire. It can be equipped with sprinklers. It is a good insulator of heat. The use of steel beams should be avoided when corrosive gases exist.

D Wood Decking, 2½ in. and Thicker, on Reinforced Concrete Beams.—About the same as I–B, except that the reinforced concrete beams are fire-resistive. This provides an insulating deck on fire-resistive supports. It requires more time for erection than the preceding types, except where pre-cast concrete beams are used.

E Arched Wood Roofs.—Proprietary roof types consist of a wooden vault built up of light wooden purlins in a diagonal pattern, or of specially designed panels sheathed with wood. Successful forms of this construction are those built under the designation of "Lamella" construction and "No-Truss" construction. The former is capable of structural analysis; the latter is designed according to empirical rules established by test. All these types require either buttresses or tie rods. They can be used for roofing large areas without columns or trusses. Their appearance and acoustics are good. They are of light weight, easily erected and a fair insulator of heat. They are combustible but can be built in a slow burning type, though not often done.

Laboratory tests of large scale glued laminated timber arches have demonstrated these conform substantially to the elastic theory of arches and can be used for structures of considerable extent.

F Fireproofed Wood Sheathing or Decking.—The use of fireproofed wood in any of the above types will increase the fire resistance of the sheathing or decking itself.

II—Decks of Various Non-Combustible Materials in Sheets, on Steel Purlins

Decks of this type are light in weight, can be erected quickly, but while the material is incombustible, the roof is subject to failure from warping or disintegration when exposed to fire and water. If sufficient pitch is provided no other roof covering is required except for insulation. Some types are difficult to make tight against wind-driven snow. In selecting these roofs exposure to corrosive gases and to peculiar atmospheric conditions such as salt air should be considered.

A Black or Galvanized Steel Sheets.—The sheets are 18 or 20 gage with ribs of various shapes formed longitudinally about 4″ to 6″ centers. This construction is light weight, but requires insulating material if heat losses are to be prevented. An insulating board is desirable on top of the steel decking to prevent buckling and to provide a base for the application of roofing. This type of decking is not suitable for roof coverings that require nailing. It must be painted.

B Corrugated Steel Sheets Coated With Asphalt and Asbestos Felt.—These are suited to buildings not heated which have roofs with proper slope. For heated buildings, additional roof covering and insulation should be provided as under II–A. It does not require painting. It is not suitable for roof coverings that require nailing.

C Corrugated Galvanized Steel Sheets.—This type is low in cost, light weight, and not permanent. It has no insulating value. It is not suitable for roof coverings that require nailing.

D Corrugated Non-Ferrous Sheets.—This type of roof is durable, if expansion is properly provided for, and is light in weight. It has no insulating value. No roof covering or painting is required. It is not suitable for roof coverings that require nailing.

E Corrugated Asbestos Sheets.—This type of roof needs no painting, and has some insulating value. The sheets are relatively brittle and not suitable for structures subject to severe vibration or impact.

III—Concrete Decks

Concrete decks can be covered, where required, with any type of roofing; where nailing is required, a nailing composition finish may be applied or nailing strips embedded in the concrete. They are durable when properly designed and constructed. Light weight aggregate may be used to reduce weight and increase insulation. Climatic or use conditions may require insulation.

A Cast-in-place Slabs on Unprotected Steel Beams.—This construction is non-combustible, but not fire-resistive. It requires more time to construct than pre-cast slabs, but shores are not necessary. It is a heavy type.

B Cast-in-place Slabs on Protected Steel Beams.—This is fire-resistive. It requires more form work than "A", and for other than concrete protection requires more time for erection. It is a heavy type.

C Cast-in-place Slabs on Reinforced Concrete Beams.—This is fire-resistive. Construction is slower than "A" and shores may interfere with other work. It is heavier than "A" and for long spans heavy supporting members are required.

D Cast-in-place "Flat Slab" Construction.—This has high fire resistance. It provides a ceiling free from beams. Shores are ordinarily used in construction.

E Cast-in-place Concrete T–Beams.—This is fire-resistive. Shores are required for construction. The use of hollow tile fillers increases the insulating value and provides a flat ceiling.

F Pre-cast Concrete Slabs on Unprotected Steel Beams.—This is non-combustible but not fire-resistive. It may be made fire-resistive by protecting the steel beams. Its use allows rapid construction. It is comparatively light in weight.

IV—Reinforced Gypsum Deck on Steel Purlins

This construction is non-combustible but not fire-resistive. It may be made fire-resistive by protecting the steel beams. It is a good insulator, light in weight, can be placed quickly. It must be covered with roofing. It disintegrates in moist conditions.

A Poured in Place With Removable Forms.—This is the simplest type. Time is required to move forms. Purlin spacing may be varied to suit building conditions.

B Poured in Place With Permanent Forms.—Has a time advantage over "A" but trouble has been experienced in moist situations from disintegration of "permanent" form material.

C Pre-cast Gypsum Slabs.—These are available in various sizes and thicknesses, solid and hollow. They have the advantages of quicker erection and cleanliness over types "A" and "B".

V—Long Span Interlocking Slabs

They must be laid on slopes steep enough to provide sufficient drainage. They can be insulated on the under side. Erection of these slabs is quickly done.

A Interlocking Concrete Slabs on Unprotected Steel Purlins.—This is non-combustible but is not fire-resistive. The weight may be reduced by using light weight aggregate.

B Interlocking Cast Iron Plates on Unprotected Steel Purlins.—This is non-combustible but is not fire-resistive.

RELATIVE MERITS OF DIFFERENT TYPES OF ROOF STRUCTURES

The ratings below represent an approximate gradation from those types of roofs which are indicated to possess the property in question to the greatest degree (Class 1) to those types which possess that property in lesser degree (Class 3), when compared under similar quality of construction and use conditions.

Type of Roof	Fire Resistance	Insulation Qualities	Durability	Economy of Construction	Rapidity of Construction	Economy of Maintenance	Ease of Alterations	Lighting Qualities	Appearance	Resistance to Corrosive Gases	Resistance To Earthquake Damage	Resistance to Tornado Damage
I A	3	2	2	1	1	2	1	3	2	1	2	3
B	2	1	2	1	1	2	1	2	2	1	2	2
C	3	1	1	1	1	2	2	2	2	3	2	2
D	2	1	2	2	2	2	2	2	2	2	2	2
E	3	2	2	2	2	2	2	2	1	2	2	2
II A	2	3	3	1	1	3	1	2	3	3	1	3
B	2	3	2	1	1	2	1	2	2	2	1	3
C	2	3	2	1	1	3	1	2	3	3	1	3
D	2	3	2	1	1	2	1	2	3	2	1	3
E	2	2	2	1	1	2	2	2	2	1	3	3
III A	2	3	1	2	2	2	3	2	2	3	2	1
B	1	3	1	3	3	1	3	2	1	1	2	1
C	1	3	1	3	3	1	3	2	1	1	2	1
D	1	3	1	3	3	1	3	1	1	1	1	1
E	1	3	1	3	3	1	3	2	2	1	2	1
F	2	3	2	2	2	2	2	2	2	3	2	1
IV A	2	1	2	2	3	2	3	2	2	3	2	2
B	2	1	2	2	3	2	3	2	2	2	2	2
C	2	1	2	2	2	2	2	2	2	3	2	2
V A	2	3	2	2	1	1	1	2	2	3	2	2
B	2	3	2	2	1	1	1	2	2	3	2	2

Appendix H

(8) CAUSES OF DUST EXPLOSIONS IN GRAIN ELEVATORS AND METHODS OF OBVIATING THE HAZARD

A. L. Sparks, Chairman, Sub-Committee; R. E. Mohr, F. R. Judd, O. G. Wilbur, E. Christiansen, L. C. Hinsch.

Introduction

Since the hauling of grain is one of the principal sources of revenue for American railroads, and being a product that is not likely to be transported in large volume by motor truck, the railroads will necessarily be interested in the storage and handling of

grain indefinitely. Many of the large terminal elevators are owned by the different railroad companies on whose lines they are located, and while they are not generally operated by the railroads, any hazards which imperil human life places heavy responsibility upon the owners.

Quoting from U.S. Department of Agriculture, on Dust Control in Grain Elevators, written by Hylton R. Brown and J. O. Reed:

"From 1919 to February 4, 1933 dust explosions in the United States in plants handling grain and grain products caused the loss of 277 lives, injury to 487 employees, and property damage amounting to more than $30,000,000. As more than one-fourth of the loss in life and more than one-half of the property damage occurred in grain elevators, special attention has been directed to the elimination of the dust-explosion hazard in the grain elevating industry.

"The requirements for a dust explosion are (1) dust in suspension in air in a certain proportion, and (2) some means of igniting this dust and air mixture. Such explosion, then, may be prevented by using equipment which will eliminate all sources of ignition around the plant, or by controlling the dust and air mixture so that no explosive dust clouds can be formed. For some time attention was directed to the elimination of open flames around plants where it was possible for the explosion hazard to exist. When it was found that electric sparks, blown fuses, broken electric lamps, hot bearings, friction fires, metallic sparks, static electricity, and fires caused by spontaneous combustion could ignite the dust, however, attention was turned to the development of equipment for controlling the dust."

Prior to 1919 considerable attention was given to the study of grain dust explosions on threshing machines in the northwestern wheat belt, by representatives of the Bureau of Chemistry for the U.S. Department of Agriculture and information on early experiments may be found in a bulletin on "Dust Explosions" published by National Fire Protection Association, written by David J. Price and H. H. Brown. Following their campaign a determined effort was made by the Terminal Elevator Grain Merchants Association to find some more successful method for prevention of dust explosion. They conferred with other national organizations and a committee was appointed, the membership of which was made up from representatives of the following organizations:

Mutual Fire Prevention Bureau
National Board of Fire Underwriters
National Fire Protection Association
National Safety Council
Railway Fire Protection Association
Terminal Elevator Grain Merchants Association
Underwriters Grain Association

At a meeting of this committee in Chicago, June 11, 1923, the view was expressed that control of floating dust would lessen explosion hazard probably 75 per cent.

The Bureau of Chemistry, U.S. Department of Agriculture, in their investigations dealing with dust explosions, learned that many of the dust-collecting systems installed in grain elevators throughout the country could not be used or were dismantled because of the objection of the officials having jurisdiction over the weighing of the grain. The weighing departments stated that grain weights are greatly affected by the action of suction used in the collection of the dust. Reports of tests conducted by a number of elevator operators, however, indicated that the weight of the dust removed is almost negligible. Some men experienced in handling grain have stated that less dust is removed by suction than is lost in handling grain by means of poor machinery, with no dust-collecting equipment.

Confronted with these conflicting statements, the Bureau of Chemistry made a study of the effect of dust collection on the weight of grain. The results showed that much depended upon the design and installation of the dust-collecting equipment. In

many cases the equipment seemed to have been installed with no knowledge of the fundamentals of good design. In some cases the claims of weighing departments that grain had been drawn out by improper application of suction to remove the dust at certain points between the car which was being unloaded and the scales, were probably correct. No information concerning a generally accepted method of applying suction or the proper equipment to use could be obtained. Every elevator seemed to have its own system of dust control and no standards existed. None of the systems were so installed as to permit inspection, nor were they so designed that it would be impossible to lift grain by increasing the speed of the fan, with a corresponding increase of suction.

To overcome objection of weighmasters to application of suction apparatus because of the opportunity of removal of grain and lessening of weight, valves have been designed and successfully operated in the air suction trunk lines for controlling the velocity of air. These valves may be set and sealed so that just sufficient air velocity is obtained at suction hoods to take up the dust in suspension and not remove grain. These valves are generally close to the heads.

The results of these investigations showed the necessity for a detailed study of the problems of controlling the dust conditions in grain elevators.

A committee made up of representatives from various national organizations set about conducting experiments and making actual working tests with a view to acquiring information with which to design acceptable dust removal equipment. They arranged with the Van Dusen–Harrington Company, elevator operators, and Day Company, manufacturers of dust collecting devices, for the installation of a test system at Crescent H Elevator in Minneapolis.

A complete report of the installation and test is given in a bulletin entitled, "Removal of Floating Dust in Grain Elevators", published by the National Safety Council, 168 No. Michigan Ave., Chicago. In their test system dust collecting hoods were placed at six principal points as follows:

1. Where car unloading hopper discharges on to belts.
2. Where unloading belt discharges into elevator boot.
3. Where elevator leg buckets pick up grain in boot.
4. Where buckets discharge into spouts at head of legs.
5. Where spouts in head house discharge into garners.
6. Where valves discharge from garners on to belts to loaders.

The test was considered successful and the bulletin says the system was approved by the Underwriters Laboratories at Chicago, and by the State Industrial Commission of Minnesota. This installation has been in use since 1924, and is reported by the owners to be still in successful operation.

U.S. Department of Agriculture Bulletin No. 1373, dated February, 1926, describes a recommended system similar to that installed at Crescent H Elevator, and concludes by saying, "Dust collection in grain elevators may not prevent explosions, but it will keep a small dust ignition from developing into a disastrous explosion."

Methods of Obviating the Hazard

In an effort to attain a higher degree of efficiency in dust control, elevators have been equipped with twin dust collecting hoods at every point where a belt conveyor discharges grain. One hood is placed above the point of discharge to collect dust that would float into the air and the second hood is placed below the discharging belt in such location as will catch the heavier dust that clings to the belt and is dropped on the floor after the belt has discharged and turned on the pulley.

In disastrous general explosions there is seldom, if ever, sufficient evidence left to give a definite clue as to the real cause of the explosion. As has been said, dust in suspension with proper atmospheric conditions may cause explosion from a very small ignition, and since it is impossible entirely to remove dust, even though all floating dust is removed from an elevator building, there still remains danger of an explosion within the elevator legs or boots where new dust is being formed by the constant agitation and friction of the grain.

Leg casings should be provided with ample size vents on the roof, of the same cross-section as the casings. Since explosions will escape at the weakest points, certain types of vents with trap doors on top that open at the instant of the explosion will allow the force to spend itself, preventing severe damage to the casing in the building and lessening the hazard of a general explosion spreading to other parts.

Storage bins should be vented to the roof to provide an outlet for the air displacement during the loading of the bin, otherwise the air, laden with dust in suspension, will find its way into the elevator areas and become a hazard.

The design of the general elevator structure enters largely into the question of minimizing the explosion hazard.

Horizontal surfaces and ledges, inaccessible for cleaning, should be avoided so far as possible, and where necessary, should be inclined as steeply as possible to prevent accumulation of dust.

Interior walls should be finished as smooth as practicable. Experiments have proven that the fine dust that would cling to rough walls is by far more dangerous than the heavier dust.

Large window areas should be introduced wherever practicable and glazed with ordinary glass in such manner as will offer least resistance to release in case of explosion. The greater the areas of light type of construction, the less damage will result from explosion to the heavy concrete construction.

Ignition may be caused by electric sparks, blown fuses, broken lamps, hot bearings, friction fires, metallic sparks, static electricity and spontaneous combustion fires. It has been proved that static electricity is responsible for some explosions, and the National Fire Protection Association in 1929 published a bulletin, "Belt Dressing for Eliminating Static", edited by P. W. Edwards and J. O. Reed, of the U.S. Department of Agriculture, in which the following statements appear:

"Static electrical charges are generated on power transmission belts in three ways: (1) by friction of the belt on the pulley; (2) by separation of the belt from the pulley; (3) to a less extent by the friction of the atmosphere on the belt.

"On conveyor belts the charges are generated by the same means, and in addition by the friction of the conveyed material on the belt.

"Static charges on machinery are caused by—

(1) Induction.
(2) Transmission from other sources such as drive pulleys and
(3) By the friction of the material passing through the machine."

It further states that static electricity can be removed from belts and other surface by grounding systems, humidifying the air sufficiently, ionizing the air in contact with the belt or other surface by means of a gas flame or by the silent discharge of high frequency and high voltage current. Static electricity can be eliminated by special belt dressings.

The bulletin also gives the following formula for a belt dressing:

"A good rubber belt dressing can be prepared by mixing 18 parts of lampblack with 82 parts of good spar varnish. A smaller quantity of lampblack may prevent most of

the cracking which develops after the above dressing is used for several months. The dressing must dry on the belt before running.

"A non-flammable thinner for the varnish can be prepared by mixing equal volumes of carbon tetrachloride and varnish makers' and painters' naphtha.

"A non-static leather belt dressing which has considerable merit consists of 100 cc. liquid fish glue, 80 cc. glycerine, 100 cc. sulphonated castor oil, 170 cc. water, 82 grams lampblack, and 20 cc. of two per cent ammonium hydroxide. These proportions may not be the best for all conditions. In some cases better results will probably be obtained by increasing the quantities of fish glue and glycerine. It may be easily applied with a brush while the belt is moving. It is not necessary for the dressing to dry before running the belt. If the belt has not been properly maintained this dressing will cause the belt to stretch."

Conclusions

The hazards of dust explosions can be reduced by—

(1) Good housekeeping to prevent accumulation of static dust.
(2) Dust-tight electric equipment.
(3) Plenty of ventilation to prevent atmosphere from becoming charged with explosive dust.
(4) Dust collection by fan produced suction—to remove dust in suspension at all points where grain is agitated.

"Good Housekeeping" is what the phrase implies—preventing dust accumulations on floors, walls, sills, beams, etc.

It is, of course, very essential that dust-tight cabinets be provided for all switches, fuses, circuit breakers, etc., and all lamps should have vapor proof enclosures.

Plenty of windows, doors, etc., that can be kept open during operation should be provided in grain elevator designs. Special attention should be given to ventilation of basements. Being below ground, with loading and receiving tracks necessarily close to the building, and generally with other buildings on all sides, windows and areaways are reduced to the minimum number and size. Fans should be installed to facilitate basement ventilation.

Scale hoppers and garners should be vented direct through the roof to the open air with vents of ample cross-section. Scale curtains should be tight, with special attention to corner slide levers to prevent dust leakage.

Dust collection is generally performed by means of suction through sheet metal pipes and motor-driven exhaust fans, which take the dust from belt loaders and floor sweeps through dust traps, that permit the grain to fall through and be salvaged, thence to a dust bin from where dust is burned, loaded out or otherwise disposed of.

Where grain weighing authorities object to dust being wasted, it is gathered and sent to the scale on which grain is weighed, or is turned back into the bins.

It is a very easy matter to overload a plant with expensive apparatus which requires so much attention and expert manipulation as to be cumbersome and defeat its own purpose.

Dust removal systems are vital and necessary to the successful operation of modern elevators, but they should be designed and supervised by engineers experienced in elevator ventilation.

One of the important features after the installation of a dust collecting system is to provide the operators of the elevator with proper diagrams and necessary instructions to the men for the successful operation of the system.

Reasonable precautions should be and generally are observed by experienced elevator operators. Warnings should be posted in conspicuous places.

No smoking, no open fires or open lights of any kind should be permitted.

No riveting or hammering against steel should be permitted when dust is in the air. Provision should be made for intercepting tramp iron.

Locomotives with fire in the fireboxes or ashpans should not cross over unloading hoppers, or come near workhouse when air is full of dust.

In designing new elevators the Safety Codes for the Prevention of Dust Explosions, as given in U.S. Department of Labor—Bureau of Labor Statistics, Bulletin No. 562 (or later editions) should be considered.

Appendix I

(9) MILL TYPE AND OTHER HEAVY WOOD CONSTRUCTION FOR RAILWAY BUILDINGS

C. L. Wenkenbach, Chairman, Sub-Committee; A. T. Upson, E. W. Niblet, E. K. Mentzer, G. A. Belden, G. H. Burnette, A. B. Stone.

Insufficient data has been assembled for a report on this subject but the Committee reports progress and recommends the subject be continued another year.

Appendix J

(10) STUDY THE ECONOMIC VALUE OF VARIOUS BASIC AND COMPOSITE MATERIALS USED IN BUILDING CONSTRUCTION AND MAINTENANCE

W. T. Dorrance, Chairman, Sub-Committee; A. C. Irwin, J. W. Orrock, Hugo Filippi, A. T. Upson, E. A. Harrison, F. R. Judd.

Progress is being made in the study of this subject but is still in the correspondence stage. It is recommnded that the subject be continued another year.

REPORT OF COMMITTEE IX—GRADE CROSSINGS

J. G. Brennan, *Chairman;*
F. D. Batchellor,
H. D. Blake,
F. J. Blickensderfer,
H. E. Brink,
John Carmichael,
C. W. Charleson,
H. M. Church,
S. N. Crowe,
L. B. Curtiss,
A. T. Danver,
C. A. Dayton,
A. R. Dewees,
G. N. Edmondson,
C. F. Edwards,
H. L. Engelhardt,
H. W. Fenno,
L. C. Frohman,
P. M. Gault,
R. C. Gowdy,
J. P. Hallihan,
H. A. Hampton,
M. V. Holmes,
A. G. Holt,
W. M. Jaekle,
Maro Johnson,
R. B. Kittredge,
W. B. Knight,
A. E. Korsell,
W. S. Lacher,
E. R. Lewis,
G. P. Palmer,
Bernard Blum, *Vice-Chairman;*
W. C. Pinschmidt,
T. M. Pittman,
L. J. Riegler,
Frank Ringer,
H. M. Shepard,
F. P. Sisson,
W. C. Swartout,
A. H. Utter,
V. R. Walling,
R. F. Wood,
Leroy Wyant,
W. L. Young,
A. M. Zabriskie,
Committee.

To the American Railway Engineering Association:

Your Committee on Grade Crossings presents herewith report on the following subjects:

1. Revision of Manual, including
   (a) Further study of the proper lighting of the base of signals where located in the center of highway. The Committee reports progress and recommends that the subject be continued.
   (b) Further study and recommendation in regard to center-road installation of flashing light or wig-wag type of signals. The Committee reports progress and recommends that the subject be continued (Appendix A).
2. Economic aspects of grade crossing protection in lieu of grade separation. The Committee reports progress and recommends that the subject be continued (Appendix B).
3. Recommend standard specifications for street crossings over railway tracks, both steam and electric. Recommended that the Specifications for Preparation of Track Structure, Width of Crossing and Approaches, for Construction of Street Crossings over Railway Tracks, Specifications for the Construction of Rail Type Street Crossings, and Specifications for the Construction of Wood Plank Crossings, be adopted for inclusion in the Manual. It is further recommended that the subject be continued (Appendix C).
4. Relative economy of different types of highway grade crossings. Recommended that the report be received as information (Appendix D).
5. Proper vertical curves on highways for grade separation projects. Recommended that the report be approved for inclusion in the Manual (Appendix E).
6. Investigate the use and report on the merits and economy of "the stop and go" type of signal, with red and green illuminated aspects, as a protective device at highway-railway grade crossings, under usual conditions and special conditions. Recommended that the conclusion be approved (Appendix F).

Respectfully submitted,

The Committee on Grade Crossings,
J. G. Brennan, *Chairman.*

Bulletin 361, November, 1933.

Appendix A

(1) REVISION OF MANUAL, INCLUDING

(a) Further study of the proper lighting of the base of signals where located in center of highway.

P. M. Gault, Chairman, Sub-Committee; Bernard Blum, H. D. Blake, H. E. Brink, H. M. Church, C. A. Dayton, H. L. Engelhardt, H. W. Fenno, M. V. Holmes, Maro Johnson, R. B. Kittredge, E. R. Lewis, G. P. Palmer, W. C. Pinschmidt, Frank Ringer, Leroy Wyant, A. M. Zabriskie.

Conclusion

The Committee reports progress and recommends that the subject be continued.

(b) Further study and recommendation in regard to center-road installation of flashing light or wigwag type of signals.

Conclusion

The Committee reports progress and recommends that the subject be continued.

Appendix B

(2) ECONOMIC ASPECTS OF GRADE CROSSING PROTECTION IN LIEU OF GRADE SEPARATION

G. P. Palmer, Chairman, Sub-Committee; S. N. Crowe, L. B. Curtiss, C. A. Dayton, A. R. Dewees, G. N. Edmondson, J. P. Hallihan, W. M. Jaekle, Maro Johnson, R. B. Kittredge, A. E. Korsell, E. R. Lewis, Frank Ringer, A. H. Utter, Leroy Wyant.

The Committee has done considerable work on the subject but is unable to present a final report. It therefore reports progress.

Recommendation

It is the recommendation of the Committee that the subject be continued.

Appendix C

(3) RECOMMEND STANDARD SPECIFICATIONS FOR STREET CROSSINGS OVER RAILWAY TRACKS, BOTH STEAM AND ELECTRIC

V. R. Walling, Chairman, Sub-Committee; F. D. Batchellor, L. B. Curtiss, A. T. Danver, G. N. Edmondson, C. F. Edwards, H. W. Fenno, P. M. Gault, R. C. Gowdy, J. P. Hallihan, H. A. Hampton, M. V. Holmes, W. M. Jaekle, W. B. Knight, H. M. Shepard, W. L. Young.

The study of this assignment has been carried on the last two years. The preparation of specifications was not sufficiently advanced during the first year for presentation at the 1933 Convention.

This year, four specifications are furnished for your consideration. These have been submitted to the Roadway Committee, American Society of Municipal Engineers and American Transit Association, with whom your Committee has been instructed to collaborate, and no exceptions have been taken.

(1) Specifications for preparation of track structure, width of crossing and approaches for construction of street crossings over railway tracks.

(2) Specifications for the construction of rail type street crossings.

(3) Specifications for the construction of wood plank street crossings.

(4) Specifications for the construction of highway crossings surfaced with oil processed gravel.

(1) SPECIFICATIONS FOR PREPARATION OF TRACK STRUCTURE, WIDTH OF CROSSING AND APPROACHES, FOR CONSTRUCTION OF STREET CROSSINGS OVER RAILWAY TRACKS

General

1. These specifications cover drainage, foundation, track work and crossing approaches in connection with construction of street crossings over railway tracks. They must be carried out in detail and with good workmanship.

Drainage

2. A requisite for good track is proper drainage, and this shall be provided at all crossings.

Surface ditches shall be installed, if required. Ample sub-drainage with suitable inlets and necessary provisions for clean-out shall be installed to drain thoroughly the sub-grade and prevent formation of water pockets. This drainage shall be connected to a sewer system, if available; if this is not possible connecting metal or concrete pipes shall be installed to carry the water a sufficient distance from the roadbed. Where gravity drainage is not available, a near by sump may prove an economical substitute for an outlet.

Approaches, where feasible, shall be on easy grades descending from the track a sufficient distance that storm water will be carried away from and not onto the tracks.

Ballast

3. If track is not well ballasted, or if the ballast is foul, it shall be dug out not less than two feet below bottom of the tie, not less than two feet beyond the ends of the ties and to the first rail joint each way from the crossing, and re-ballasted with good, clean, suitable ballast.

The new ballast shall conform to the American Railway Engineering Association Specifications for Ballast.

Track

4. All except sound treated ties shall be replaced with new treated ties. Sawed ties shall be used where the type of the crossing to be installed requires them. All ties shall be tie plated.

Rails throughout the crossing, and for a rail length on each side shall be renewed with new rails of the section standard in that district, unless existing rails are of full standard section.

Rail shall be so placed that there will be no rail joints within the crossing, and with joints preferably located not less than one-half rail length from the crossing. If because of the width of the crossing this is not practicable, the rail ends shall be welded to form continuous rail through the crossing.

Rails shall be double spiked to perfect line and track thoroughly and solidly tamped to uniform surface.

Width of Crossing and Approaches

5. Crossings and approaches on the right-of-way shall be of sufficient width to permit traffic to move freely and avoid a bottleneck at the crossing.

The approaches on the right-of-way shall be improved with material identical with or equal to that of adjoining street pavement.

(2) SPECIFICATIONS FOR THE CONSTRUCTION OF RAIL TYPE STREET CROSSINGS

General

1. These specifications cover second-hand or scrap steel rails of lighter weight section than the running rails for use in the construction of rail type crossings. The specifications must be carried out in detail and with good workmanship.

Track Structure, Width of Crossings and Approaches

2. Track structure, width of crossings and approaches shall be designed and constructed in accordance with the specifications covering this work for street crossings over railway tracks, both steam and electric.

Materials and Installation

3. Intermediate and approach rails shall be of fair second-hand or good scrap quality. Curve-worn rail with excessive side head wear shall not be used. Care shall be taken to use rail showing approximately equal top head wear to provide level surface for the crossing. The variation in height of rails shall not exceed ⅛-inch.

The space between running rails shall be filled with intermediate crossing rails, the number to be used to be determined by section of rail and requirement that distance between side of heads of adjacent rails shall not exceed four inches. The number of approach crossing rails to be used shall be determined by the same stipulation, with the additional requirement that distance from side of head of outside approach rail to edge of highway pavement shall not exceed four inches.

Creosoted hardwood shims not less than six inches in width and of proper thickness to bring tops of crossing rails level with tops of running rails shall be provided and securely nailed to each tie. Sawed cross-ties shall be used to provide full and even bearing for the shims.

All crossing rails shall be securely fastened with spikes at every third tie on each side of base of rail with spiking so staggered that rails will be spiked to each tie. Where dimensions between edges of adjacent rail bases do not permit such spiking, rail bases shall be notched to fit.

Crossing rails adjacent to running rails shall be so located that running rails may be renewed without necessity of removing crossing rails. It may be necessary to cut off a portion of the base of crossing rail to accomplish this, which shall be done where required.

Tie plate interference may prevent spiking down the edges of bases of crossing rails adjacent to the running rails. Where such spiking cannot be done, these crossing rails shall be fastened to the adjoining crossing rail with bolts not less than ¾-inch in diameter, spaced not less than six feet apart. Each such bolt shall be provided with pipe separator of proper length to make tight fit to prevent movement of crossing rail adjacent to running rail. If location of outside approach rail is too near the end of tie to be spiked down securely, then base of rail should be notched for proper spiking or rail bolted to adjacent crossing rail in manner just described.

All outside ends of crossing rails shall be bevelled not more than 45 degrees from the horizontal to prevent possible damage through being struck by dragging equipment.

For highway crossings in signal territory, the center rail shall be replaced with proper dimensioned creosoted timber for insulation.

The final elevation of top of rail shall be even with the highway pavement. If pavement beyond the track is of concrete a space of two inches shall be provided between ends of ties and the pavement in which shall be placed a bituminous felt strip two inches in thickness for the full depth and width of the pavement. If pavement is of construction other than concrete, a 4″ × 18″ creosoted timber header shall be placed on edge the full length of pavement to retain pavement, with same spacing and application of felt strip as for concrete pavement.

After the complete installation of the crossing rails, the openings on both sides of the running rails shall be filled to top of rail with poured bituminous filler. All other spaces between rails and between outside crossing rails and felt strip shall be filled to top of rail with the same material or other suitable material.

(3) SPECIFICATIONS FOR THE CONSTRUCTION OF WOOD PLANK STREET CROSSINGS

General

1. These specifications cover the use of wood plank in the construction of this type crossing. The specifications must be carried out in detail and with good workmanship.

Track Structure, Width of Crossings and Approaches

2. Track structure, width of crossings and approaches shall be designed and constructed in accordance with the specifications covering this work for street crossings over railway tracks, both steam and electric.

Materials and Installation

3. It is recommended that creosoted planking and shims or furring strips shall be used. The accessibility of the various species of wood may determine the kind of timber and the kind of treatment, if any, that is most economical for use by an individual railway. This consideration should be the governing factor in the selection of the material to be used. When treated timbers are used the mill work required shall be done before treatment.

Crossing plank shall be of eight and ten-inch widths, not less than four inches thick, and shall be surfaced one side and one edge for uniform thickness and width. Commercial length planking of most economical lengths for the individual crossing shall be used. Length of planks shall be chosen to stagger joints so that no two adjacent planks shall have their intermediate ends on the same tie.

Shims not less than six inches in width and of proper thickness to bring tops of crossing planks level with top of running rails shall be provided and securely nailed to each tie. Sawed cross-ties shall be used to provide full and even bearing for the shims.

Planks shall be laid with ⅛-inch to ⅜-inch opening between edges. Each plank shall be securely spiked down at its ends and to every other tie, using two boat spikes driven diagonally to prevent heaving of the plank. Plank ends shall be bored for boat spikes to prevent splitting. For crossings where rail is between five inches and six inches in height, boat spikes ½″ × 10″ shall be used. Where rail is more than six inches in height boat spikes ½″ × 11″ shall be used.

Planks may be fastened down with lag screws instead of boat spikes. Where lag screws are used they shall be of same size as specified for boat spikes, but only one lag screw in each plank and in every other tie shall be required. Planks shall be bored for lag screws with hole $\frac{1}{16}$-inch larger diameter than that of lag screw, and shall be countersunk for washer and lag screw head.

The top of the plank crossing shall be even with the highway pavement. The edges of outside planks shall extend to and may project not more than one inch beyond ends of ties. If pavement beyond the track is of concrete, a space of one inch shall be provided between the edge of planking and the pavement. If pavement is of construction other than concrete a 4″ × 18″ creosoted timber header shall be placed on edge the full length of the pavement to retain same and a space of one inch shall be provided between the edge of planking and face of header.

Flangeway guards shall be installed in all important crossings; they shall be either dapped plank, old steel rail balled in, or of suitable patented type.

All outside ends of crossing planks and flangeway guards shall be bevelled not more than 45 degrees from the horizontal to prevent possible damage through being struck by dragging equipment.

(4) SPECIFICATIONS FOR THE CONSTRUCTION OF HIGHWAY CROSSINGS SURFACED WITH OIL PROCESSED GRAVEL

General

1. Oil processed surfacing shall consist of mixing No. 2 asphaltic road oil and a mineral aggregate at a mixing plant, hauling it to the crossing to be surfaced, and spreading, manipulating and compacting the mixture in accordance with these specifications.

Track Structure, Width of Crossings and Approaches

2. Track structure, width of crossings and approaches shall be designed and constructed in accordance with the specifications covering this work for street crossings over railway tracks.

Mineral Aggregate

3. The mineral aggregate shall be the product of a crushing and screening plant and shall be composed of hard durable fragments of rock and sand containing or having incorporated in it, limestone dust, iron oxide, or other binding material in such proportion that the whole will be of a homogeneous material complying with the grading and other requirements specified herein below. The material shall be uniformly graded from fine to coarse, and when tested by means of laboratory screens and sieves, shall meet the following requirements by weight:

Passing a screen having circular openings 1″ in diameter—100 per cent.
Passing a screen having circular openings ¾″ in diameter—85 per cent to 100 per cent.
Passing a No. 10 mesh sieve—45 per cent to 65 per cent.
Passing a No. 200 mesh sieve by washing—8 per cent to 15 per cent.

Asphaltic Road Oil

4. (1) Asphaltic content not less than 80 per cent nor more than 90 per cent by weight of 100 per cent penetration asphalt, 100 per cent grains weight, 5 seconds, 77 degrees Fahr.

(2) Flash point—Open cup method—not lower than 270 degrees Fahr.

(3) Specific viscosity—Engler—at 122 degrees Fahrenheit—not less than 350.

(4) Water in sediment—not more than 2 per cent combined.

(5) Paraffin—not more than 2 per cent.

(6) Carbonaceous Flakes (Carbenes) basis per cent of 100 penetration asphalt, not more than 0.50 per cent. Tests on road oil are to conform to the most recent A.S.T.M. Standards.

Mixing

5. The amount of this No. 2 oil shall be from 5 per cent to 8 per cent of the weight of the aggregate. Oil shall be from 150 degrees to 200 degrees Fahr. when added to the mix, and shall be added accurately by weight. Each batch of this material shall be mixed for at least ten seconds dry and then for a period of forty to fifty seconds after all ingredients are in the mix, and until a uniform mixture of unchanging appearance is obtained with all the particles of aggregate coated with oil.

The amount of moisture in the gravel or crushed rock at this time of the mixing shall not exceed 2 per cent of the weight of dry aggregate.

Application

6. After track has been prepared in accordance with Section (2) of these specifications, a flangeway rail shall be applied. Such rail shall be laid on its edge so that its head shall fit snugly to the web of the running rail and securely fastened to prevent lateral movement. This may be done by placing a scrap angle bar spanning two ties against the base of the flangeway rail, at least four to each such 33-ft. rail, and spiking angle bars securely to each tie.

Ballast material shall then be brought up to a point two and one-half inches below the top of rail and shall be thoroughly tamped and rolled to insure a uniform, level and compact base for the oil processed gravel surfacing material.

If paving is done between tracks, five inches of sub-base consisting of specified rock or gravel, well rolled and compacted, shall be applied—the top of this sub-base to be two and one-half inches below the top of rail and finished grade of the highway.

Three inches of oil processed gravel shall now be spread over the prepared sub-base. It shall be well rolled until the mass has been fully compacted and thoroughly hand-tamped along the flangeway rail. During the process of rolling it is advisable to wipe the surface of the roller with kerosene to prevent oil processed gravel from sticking to it.

Three inches of oil processed material spread loose will compact about one-half inch and when completed, the surface of the finished crossing should be about level with the top of the running rails, but if slightly higher it should be left to be pounded down by traffic.

As soon as the oil processed gravel has been laid and compacted, traffic may be turned over the new surface immediately. If the finished surface is soft or sticky, cement shall be broomed over the entire area and a layer of fine dry sand spread over it, after which a heavy hand roller shall be used to imbed the sand in the paving.

Approximately a cubic yard of oil processed material shall be kept near the crossing so that any low spots that may be caused by vehicular traffic can be built up by application of a few shovels full of the material, as required.

Laying of oil processed gravel should preferably be done in warm, dry weather, and under no conditions during freezing weather. When gravel is put down on cold days it shall be applied in layers well compacted and metal, wood or concrete surfaces next to the layer of gravel shall be mopped with one coat of cut back asphalt.

If the oil processed material is laid as above, and properly and economically handled, one ton will cover about eight square yards of surface, after it has been compacted to a finished depth of two and one-half inches.

Recommendation

Your Committee makes these recommendations:

(a) That the following specifications be adopted as recommended practice and published in the Manual:

(1) Specifications for preparation of track structure, width of crossing and approaches for construction of street crossings over railway tracks.

(2) Specifications for the construction of rail type street crossings.

(3) Specifications for the construction of wood plank street crossings.

(b) That Specification (4)—"Specifications for the construction of highway crossings surfaced with oil processed gravel," be received as information.

(c) That this subject be continued for further study and preparation of specifications for other types of street crossings.

Appendix D

(4) RELATIVE ECONOMY OF DIFFERENT TYPES OF HIGHWAY GRADE CROSSINGS

F. D. Batchellor, Chairman, Sub-Committee; F. J. Blickensderfer, John Carmichael, C. W. Charleson, H. M. Church, S. N. Crowe, C. A. Dayton, L. C. Frohman, A. G. Holt, W. B. Knight, A. E. Korsell, W. C. Swartout, A. H. Utter, V. R. Walling, R. F. Wood, W. L. Young.

The following types of crossings are generally in use:

Plank
Bituminous
Concrete
Metal

To a lesser extent paved crossings of brick, granite and wood blocks are in use.

1. Plank Crossings

(a) Untreated Plank.—Until the advent of the automobile and trucks, with improved streets and highways, crossing plank was almost universally used for highway crossings. Since then, in some localities, it did not stand up under the traffic and substitutes began to appear. Today, particularly in the Western and Southern states, plank is still generally in use. It is also used in all states for minor crossings.

(b) Treated Plank.—These planks are being extensively used as they overcome, to some extent, the trouble which has been experienced on account of failure through decay. They have been used in the following way:

(1) Built on same plan as untreated plank crossings.
(2) Built same as above but with a protective covering for wearing surface of either rubber belting or bituminous material.
(3) Built with the plank parallel with the center of the highway instead of parallel with the center of track.
(4) Built in sections.

(c) Asphalt Plank.—These have been tried out but are still in the experimental stage.

A plank crossing, to make a satisfactory crossing, must be substantially built and securely fastened to the ties. It must be promptly and adequately repaired as needed.

If built and maintained as above, they make satisfactory highway crossings.

2. Bituminous Crossings

This type of crossing was one of the first substitutes for plank crossings and is extensively used in the Eastern and Middle Western states. There are several kinds, as follows: (a) bituminous material mixed with stone or gravel at crossings, (b) natural rock asphalt and (c) ready mixed bituminous material.

(a) Mixed at Crossing.—This type was one of the first bituminous crossings generally in use. The wearing surface is made by mixing the bitumen or emulsion, which is furnished in barrels, with rock or gravel. It requires considerable labor and more or less care in mixing the preparation.

(b) Natural Rock Asphalt.—The rock asphalt is a natural product and is shipped from the mine in cars ready for use and layer applied on top of stone or gravel for wearing surface.

(c) Ready Mixed.—This type of bituminous crossing is one of the newest. It is readily handled as it is mixed at the plant and shipped in cars to the crossing. It is applied as a wearing surface by placing a layer on top of stone or gravel.

All bituminous crossings should be thoroughly rolled or tamped, preferably with a heavy power roller. They should be patched and rolled or tamped whenever depressions occur. For heavily traveled crossings they should have a metal flangeway, a rail on each side of the running rail, or one rail on inside of running rail. Heavy traffic on the highway improves this type of crossing.

Bituminous crossings, if built to the proper specifications and if properly maintained, make a satisfactory highway crossing.

3. Concrete Crossings

These types of crossings are used in cities and heavily traveled highways. The first concrete crossings were not altogether satisfactory as they chipped on the edges and in some instances cracked on account of heaving. In today's crossings these troubles have been overcome. There are the following types of concrete crossings:

(a) Solid Concrete.—This type of crossing is not used to any great extent, due to the fact that the track cannot be readily repaired. However, where track does not have to be disturbed for a good many years, it makes a satisfactory crossing as it requires practically no maintenance.

(b) Concrete Plank.—The earlier types of concrete crossings were concrete plank and were not altogether satisfactory. However, if properly constructed and securely fastened to the ties, they make a satisfactory crossing.

(c) Concrete Slab.—This type of crossing is being used in cities and on main highways, particularly in the Eastern and Middle Western states. There are various designs of slabs and in some cases metal forms are provided and filled in with concrete at the crossing. When properly constructed and installed, this type of crossing is satisfactory.

4. Metal Crossings

There are two types of metal crossings; rail and plate.

(a) Rail.—This type of crossing has in scattered cases been in service for a good many years, especially on side tracks or unimportant branch lines. Lately, however, they are being more extensively used. The best types of this crossing are filled with concrete or bituminous material between the rails. These make a satisfactory crossing if properly installed. Provision should be made so that running rail can be renewed without tearing up crossing.

(b) Plate.—Steel and iron plates, either fabricated, rolled or cast, are the latest type of crossing. Those which were first used were slippery and did not stand up under heavy loads. Those of today have overcome these objections by the use of projections on the plate and heavier design of the plate. They are used mostly in cities and heavily traveled highways. If of proper design and securely fastened to ties, these make a satisfactory crossing.

5. Paved Crossings

This type of crossing has been used mostly to conform to the paving on the highway adjacent to it. There are not many of these crossings being put in today.

It will be noted that practically all of the crossings given above will make satisfactory crossings if properly constructed and maintained. As there are so many varying conditions at different crossings, we cannot recommend any of them as best for all crossings.

Particular attention is called to the fact that none of these crossings will give satisfactory results unless special attention is given in preparing the subgrade and track for the crossing. The track should be well drained, well ballasted, well tied, well tamped and lined and surfaced before crossing is put in.

Below is a statement giving some of the advantages and disadvantages of the various types:

Type of Crossing	*Advantages*	*Disadvantages*
Plank (Wood)	Can be installed without much trouble. Low first cost. Can be designed to fit any type Xing. Can be readily taken up to repair track.	High maintenance cost. Short life. Frequent maintenance. Liability of plank coming loose and being caught by dragging equipment or damaging tires on autos.
Bituminous	Can be installed with track force. Can be used for surface for space between tracks. Low first cost. Can be designed to fit any type Xing. Improves with traffic on highway. Makes smooth crossing.	Gets rough unless patched from time to time. Liability of bitumen breaking next to running rail. Has to be dug up to repair track.
Concrete (Slab)	Long life. Low maintenance cost. Makes smooth crossing.	High first cost. Preferable to use sawed ties. Somewhat expensive to take up to repair track.
Concrete (Solid)	Long life. Low maintenance cost.	High first cost. Expensive to repair track.

Type of Crossing	*Advantages*	*Disadvantages*
Rail	Long life. Low maintenance cost. Makes smooth crossing. Material generally available.	First cost high. Difficult to repair track.
Plate	Long life. Makes smooth crossing.	First cost high. Preferable to use sawed ties. May be broken by derailed equipment. Brine drippings liable to affect life. Necessary to insulate in automatic signal territory.

To find out which is the best and most economical type for any particular crossing, the following should be determined:

(1) Kind of track structure.
(2) Number of times crossing has to be disturbed to repair track.
(3) Availability and cost of crossing material.
(4) Amount of travel on highway.
(5) Amount of travel on railroad.
(6) First cost of crossing.
(7) Life of crossing.
(8) Cost of maintenance per year.
(9) Kind of pavement each side of crossing.
(10) Weather conditions.
(11) Traffic reasons.

After having determined the above, we suggest the following formula be used to determine the most economical type of crossing.

$$\frac{a}{b} \text{ plus } c \text{ plus } d \text{ equals } e$$

$a =$ First cost of crossing per square foot.
$b =$ Estimated life in years.
$c =$ Interest on first cost per square foot.
$d =$ Cost of maintenance per square foot per year.
$e =$ Cost per square foot of crossing per year of estimated life.

To determine the cost per running foot of track, multiply the cost per square foot by 8½ or whatever width is required.

One of the principal items in using this formula is the estimated life of the crossing. Unfortunately, information as to this is not available and if it were, it would not apply to all crossings, unless the conditions were similar at each crossing.

The statement below is compiled from information furnished by different railroads in different states and is given only as information as to what they estimate will be the life of a crossing where conditions are similar to the crossing reported.

The summary of this statement, given at the bottom, may or may not be of value, as showing the comparative average estimated life of the various types of crossings, depending on whether or not conditions at the crossings are similar.

	Location		*Life in Years*	
Type of Crossing	*Railroad*	*State*	*To Date*	*Estimated*
Untreated Plank	C. B. & Q. Ry.	Neb.	..	5
" "	B. & O. R. R.	Ohio	6	6
" "	C. R. I. & P. Ry.	Iowa	1	5
" "	" "	Ark.	3	5
" "	E. J. & E. Ry.	Ind.	4	5

Type of Crossing	Location: Railroad	Location: State	Life in Years: To Date	Life in Years: Estimated
Treated Plank	C. & O. Ry.	Ky.	5	6
" "	Mo. Pac.	Texas	3	15
" "	K. C. Sou.	Kan.	11	18
" "	E. J. & E. Ry.	Ill.	1	8
" "	C. & O. Ry.	Ohio	.5	6
Asphalt Plank	N. & W. R. R.	Ohio	3	3
" "	C. I. & L. Ry.	Ind.	..	5
" "	" "	"	4	4
" "	C. & O. Ry.	W. Va.	5	5
" "	Mo. Pac.	Texas	3	10
" "	C. & O. Ry.	Va.	6	10
Bituminous	B. & A. R. R.	Mass.	12	22
"	C. R. I. & P. Ry.	Ark.	3	5
"	" "	"	3	5
"	" "	Mo.	3	5
"	E. J. & E. Ry.	Ind.	3	12
"	N. & W. Ry.	Ohio	2	3
"	" "	Va.	2	4
"	" "	"	2	4
"	C. I. & L. Ry.	Ind.	2	6
"	B. & A. R. R.	Mass.	9	12
"	Erie	N. Y.	4	5
"	C. & O. R. R.	W. Va.	5	8
"	" "	Ky.	.5	6
"	" "	Ohio	4	8
"	" "	Ky.	5	8
"	" "	"	5	8
"	" "	"	.5	5
"	" "	Ohio	1.5	5
"	" "	Ky.	.5	5
"	" "	"	1	5
"	W. Maryland	Md.	..	4
"	"	"	..	4
Rock Asphalt	C. I. & L. Ry.	Ind.	6	10
" "	" "	"	7	9
" "	C. & O. R. R.	W. Va.	5	5
Concrete Plank	B. & A. R. R.	Mass.	15	20
" "	C. R. I. & P. Ry.	Ill.	4	15
" Slab	N. Y. C. & St. L. Ry.	Ind.	5	15
" "	" "	"	6	15
" "	" "	Ohio	5	15
" "	" "	Ind.	4	15
" "	" "	"	4	15
" "	" "	Ohio	2	15
" "	" "	Ind.	3	15
" "	" "	"	2	15
" "	" "	Ohio	2	15
" "	" "	"	2	15
" "	C. & O. Ry.	W. Va.	.5	20
" "	Erie	N. Y.	3	15
" "	"	Ohio	4	15
Rail and Bituminous	B. & A. R. R.	Mass.	7	25
Rail and Concrete	B. & O. R. R.	Ohio	2	20
" " "	" "	"	2	20

Type of Crossing	Location: Railroad	Location: State	Life in Years: To Date	Life in Years: Estimated
Rail and Asphalt	C. R. I & P. Ry.	Iowa	4	15
" " "	" "	"	4	15
" " "	" "	"	4	15
" " "	" "	"	3	15
" " "	C. I. & L. Ry.	Ind.	6	10
Rail	C. B. & Q. Ry.	Neb.	3	20
"	" "	"	4	20
Plate	Erie	Ohio	1	20
"	C. R. I. & P. Ry.	Ill.	4	15
"	" "	Mo.	4	15
"	E. J. & E. Ry.	Ill.	5	15
"	" "	Ind.	2	12
"	" "	Ill.	3	12
"	" "	"	3	12
"	" "	"	2	12
"	" "	Ind.	2	12
"	" "	"	2	15
"	C. & O. Ry.	W. Va.	.5	30
"	S. P.	Texas	8	40
"	Mo. Pac.	La.	2	20
"	C. & O. Ry.	W. Va.	..	30

SUMMARY

Type of Crossing	Estimated Life: Minimum	Estimated Life: Maximum	Average
Untreated Plank	5	6	5.2
Treated "	6	18	10.6
Asphalt Plank	3	10	6.2
Bituminous	3	22	6.9
Concrete (Plank)	15	20	13.5
" (Slab)	15	20	15.4
Metal (Rail)	10	25	17.5
" (Plate)	12	40	18.6

Recommendation

It is the recommendation of your Committee that this report be received as information.

Appendix E

(5) PROPER VERTICAL CURVES ON HIGHWAYS FOR GRADE SEPARATION PROJECTS

E. R. Lewis, Chairman, Sub-Committee; John Carmichael, C. W. Charleson, S. N. Crowe, R. C. Gowdy, A. G. Holt, A. E. Korsell, W. S. Lacher, T. M. Pittman, L. J. Riegler, H. M. Shepard, F. P. Sisson, V. R. Walling, R. F. Wood, A. M. Zabriskie.

Definition

Highway Vertical Curve.—An easement curve designed primarily to afford safe vision and/or enough gradual change in direction to minimize angular shock.

Railroad and highway vertical curves are dissimilar because of the essential difference between railroad and highway traffic. The railroad vertical curve is designed to

counteract the tendency of the cars in a train to run together in sags and to pull apart on summits. The highway vertical curve is designed to provide safe vision for drivers of single, or at most three coupled, vehicles of comparatively short wheel base; and/or gradual change in direction while passing from one grade to another. The ends of the vertical curves farthest from the crossing of railroad and highway involved, mark the physical limits of the grade separation project. Being grade separation items, all this vertical curvature is subject to joint consideration and agreement.

Practice covering highway vision curves is fairly well established. A common minimum of safe vision required by many State authorities is 500 feet for Class I highways, the line of sight being five feet above paving surface. The vertical curve length depends on the algebraic difference of intersecting gradients, on permissible speed and on the vision required. Unlighted highways require sag curves flat enough to permit automobile head lamp rays to intercept the surface at a distance that provides sufficient length of illuminated roadway. It is apparent that "safe vision" is required essentially to protect against careless driving. Few collisions would occur if all vehicles remained in the proper lanes of travel and if stationary obstructions were kept clear of the roadway. Head-on collisions can only occur when one or both vehicles are trespassing. Tail end collisions result from reckless driving or from disregard or absence of signals. Since the 500-ft. minimum vision applies to the practically unlimited speeds of the country highway, the speed restrictions, lane markings, superior signal protection, lighting and close policing of city streets, permit the use of much shorter vertical curves with reasonable safety in cities.

Many grade separations also provide separated roadways for one way traffic. Curves for vision in such cases are not so vital. The parabolic vertical curve is the design in general use. The 500-ft. vision is by no means rigidly observed even on Class I highways in rural districts, for it is not to be supposed that in any country of wide expanse, diversified topography and gradual settlement any single standard would suffice. The class of road, the density of traffic and many local conditions govern vertical curve selection. Many paved highways follow closely the sharp grade changes and undulations of the original surface in mountainous or hilly terrain, especially in the older settled districts where summits remain sharp, while sags have been modified for drainage rather than for rideability. The complications of horizontal curves with their vision obstacles of woods, excavation slopes, buildings, etc., further influence selection of vertical curves. In order that the approach to a horizontal curve be not hidden, the vertical curve advisedly is kept wholly within the horizontal curve limits.

The sag curve, where vision is unobstructed, may be limited to mitigating angular shock. Inasmuch as an algebraic difference of five per cent of gradient involves the very flat angle of two degrees, fifty-two minutes, a vertical curve less than 100 feet long will serve such a grade change at high speeds. Sag curves heretofore have received comparatively little study, with the result that long sweeps are installed commonly for appearance sake and for little other reason. Study of sag curves not involving vision should be based on location, permissible speed and angle of intersecting grades.

Good practice in highway design of grade separations excludes horizontal curves from the structure and approach roads wherever possible. Obstructions to view are carefully avoided or eliminated. City streets usually are straight and require only change in elevations. Streets intersecting approach roads are eliminated wherever feasible. Thus the grade separation project becomes a specialty in highway design so far as vertical curvature is concerned. Whether the highway be elevated or depressed for separation purposes, the location of the point of intersection of grade lines at or near the point of crossing of the center lines of railroad and highway is usually desirable and

economical in conserving space and minimizing expense. Length of structure, underground pipe lines, etc., frequently prevent central curve location. Where a long viaduct or subway separates the highway from multiple tracks as in a railroad yard, the horizontal or drainage grade connected with vertical curves at the bottom of each approach becomes necessary. Drainage must be cared for in connection with any vertical curvature design.

Sag curves of 20 to 50-ft. length are common in grade separations in most large cities. No discomfort is felt in traveling these curves at speeds restricted to 25 to 40 miles per hour, usual maxima permitted in cities. Sight distances of 250 to 300 feet are admitted safe for these speeds. In many cases the vision curve length does not exceed 100 feet or even less. Roadway markings, policing, etc., take the place of extravagant vertical curves. Reason, rather than rule, should govern selection everywhere. The location and design of highways at grade separations should reflect a balance between maximum safety and comfort to the road user (which involves grades, alinement and horizontal and vertical sight distance) and a reasonable expenditure of funds.

Design of vertical curvature should be made to fit the conditions, eliminating any tendency to treat all sag curves in terms of vision curve lengths, to treat city grade separation vertical curves in terms of the unrestricted sweep and speeds of the open road. There is a balance of safety and economy attainable in every case which, if fairly and intelligently considered in the light of a weighted average of all the factors involved, invariably determines vertical curve lengths of greatest advantage. Beyond the limits of safety and utility, vertical curvature required should be the sole responsibility of the initiating party. Minima of 10 feet length for each 1 per cent of change in gradient for vertical curves in urban grade separation projects; and 15 feet for each 1 per cent of change in gradient for highways outside of cities are suggested. Sight distance curves merit special designs.

Recommendation

It is recommended that depression or elevation of highways required for separation from railroad grades be effected with the minimum of vertical curvature required for safety and utility.

It is further recommended that the foregoing be approved and published in the Manual.

Appendix F

(6) INVESTIGATE THE USE AND REPORT ON THE MERITS AND ECONOMY OF THE "STOP AND GO" TYPE OF SIGNAL WITH RED AND GREEN ILLUMINATED ASPECTS, AS A PROTECTIVE DEVICE AT HIGHWAY-RAILWAY GRADE CROSSINGS, UNDER USUAL CONDITIONS AND SPECIAL CONDITIONS

R. C. Gowdy, Chairman, Sub-Committee; Bernard Blum, F. J. Blickensderfer, H. E. Brink, A. T. Danver, A. R. Dewees, G. N. Edmondson, C. F. Edwards, H. L. Engelhardt, P. M. Gault, W. S. Lacher, G. P. Palmer, W. C. Pinschmidt, H. M. Shepard, W. C. Swartout, A. H. Utter, Leroy Wyant.

The "Stop and Go" type of signal has no outstanding advantages over "Wigwag" or "Flashing Light" types, and it has some serious disadvantages. Their average cost of installation is about the same as that of "Flashing Light" and "Wigwag" signals under

similar conditions, but the cost of operating them is of necessity greater because of the fact that their lamps burn continuously throughout the day and night, requiring a greater consumption of current and more frequent renewal of lamps. "Flashing Light" and "Wigwag" signals consume current and operate only while trains are passing. It is claimed that "Stop and Go" signals are identical with the usual type of highway signals, but such is not the case. Highway traffic signals indicate "Go" only when the "Stop" signals are displayed against conflicting traffic, but "Stop and Go" signals at railway crossings do not display any "Stop" signal toward trains, and in some instances the signal would not be visible from approaching trains. Ordinarily at street intersections traffic signals are displayed in four directions, but at railway crossing signals would be displayed in only two directions. Highway traffic signals stop traffic on one highway or street, permitting it to go on the other, alternating the condition, but at railway crossings trains have the right-of-way and when railroad movements are not frequent the green light might be displayed for a considerable length of time without alternating with the red light. A long display of either red or green light without change or movement is liable to cause motorists to disregard its importance.

At crossings where main tracks only are protected, but where sidings are not, and trainmen are required to flag across a street or highway, the display of a green light while a trainman was attempting to stop traffic on the highway with a flag or lamp would result in confusion, unless auxiliary manual control is provided. A green signal is generally recognized as a positive command to go, and any confliction of signals with it by hand or otherwise should be avoided. A "Flashing Light" or "Wigwag" signal calls attention to the crossing, but it does not conflict with other signals being displayed, and does not relieve motorists of their legal obligation to see that no train is approaching, and that the crossing is clear. At street and highway intersections it is noticeable that vehicles approaching green signals increase their speed in an effort to cross before the light changes. A green light at a railway crossing is an invitation to drivers to cross as quickly as possible, and is directly opposed to efforts of states and municipalities to slow down traffic at such crossings.

A steady red light is not as noticeable as a moving or flashing light of the same color, and there is less chance of all lights in a "Flashing Light" signal burning out than there is of the single red light in the "Stop and Go" type.

It is argued that "Stop and Go" signals, due to their resemblance to the usual traffic lights, would be observed by the public, but this is doubtful. It is a common occurrence for drivers to ignore traffic lights unless such lights are under police supervision, and at railroad crossings in the open country without police supervision, there would probably be a general disregard of them.

The American Railway Association, through its committees, has been working for a number of years for standardization throughout the country in grade crossing protection, and has been successful in procuring the adoption of "Wigwag" or "Flashing Light" types of signals at a great many crossings. To now recede from its position and recommendations to states and municipalities, and to call attention to the "Stop and Go" type of signal, would seriously retard progress already made.

There is at the present time no general demand on the part of the public or state or municipal authorities for the installation and use of "Stop and Go" signals, and there have been few if any complaints of the "Flashing Light" or "Wigwag" types. These latter types are generally known and recognized throughout the country as indicating railway crossings, and the number of types of signals for that purpose should be limited to as few as possible, instead of introducing new types which have been developed for crossings and intersections dissimilar to railway crossings.

In some special instances "Stop and Go" signals may properly be interconnected with railroad signals, but such cases are rare and each should be considered on its own merits, having in mind the particular conditions governing each installation.

Conclusion

"Stop and Go" signals should not be used for the protection of railroad-highway grade crossings where they are operated exclusively by the passage of trains, and their use should be confined to special locations where their observance can be enforced by police power.

Recommendation

It is recommended that the conclusion be approved and that the Joint Committee on Grade Crossing Protection, A.R.A., be notified of such conclusion.

REPORT OF COMMITTEE XI—RECORDS AND ACCOUNTS

C. C. Haire, *Chairman;*
E. Y. Allen,
Anton Anderson,
D. L. Avery,
A. M. Blanchard,
E. V. Braden,
H. T. Bradley,
R. R. L. Bullard,
E. S. Butler,
W. F. Cummings,
V. H. Doyle,
James Erskine,
W. L. Foster,
W. E. Gardner,
J. H. Hande,
A. T. Hopkins,
W. W. James,
F. C. Kane,
W. R. Kettenring,
C. A. Knowles,
P. R. Leete,
J. R. Leguenec, Jr.,
Henry Lehn,
W. M. Ludolph,
W. S. McFetridge,
E. W. Metcalf,
A. T. Powell,
H. L. Restall,
F. C. Sharood,
B. A. Bertenshaw, *Vice-Chairman;*
Chas. Silliman,
C. K. Smith,
C. R. Smith,
D. W. Smith,
F. X. Soete,
James Stephenson,
H. J. Stroebel,
D. C. Teal,
G. R. Walsh,
A. P. Weymouth,
Louis Wolf,
W. H. Woodbury,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully presents herewith reports covering the following subjects:

Group A—Miscellaneous

(1) Revision of Manual (Appendix A).

(2) Bibliography on subjects pertaining to records and accounts (Appendix B).

Group B—General Railway Engineering Reports and Records

(1) Office and drafting room practices (Appendix C).

(2) Joint facility records: (Appendix D)

(a) Appraisal methods and records for keeping up to date.
(b) Maintenance and operation reports and records.
(c) Effect of depreciation accounting.

(3) Bridge inspection report forms (Appendix E).

Group C—Maintenance of Way Reports and Records

(1) Statistical requirements of operating, accounting and other departments with respect to maintenance of way and structures, collaborating with appropriate committees (Appendix F).

(3) Forms used by railway water service departments (Appendix G).

Group E—Valuation

(1) Methods and forms for gathering the data for keeping up to date the valuation and other records of the property of railways with respect to: (Appendix H)

(a) Changes made necessary by government regulations.
(b) Simplicity and practicability of use.

(2) Methods used in recapture proceedings (Appendix I).

Group F—Accounting Practices Affecting Railway Engineering

(2) Developments under I.C.C. Order No. 15100—Depreciation Charges of Steam Railway Companies (Appendix J).

(3) Methods for avoiding duplication of effort and for simplifying and co-ordinating work under the requirements of the I.C.C. (Appendix K).

Action Recommended

(1) That the report under Appendix A be approved as recommended practice and printed in the Manual.

(2) That Appendix B be received as information and the subject continued.

(3) That the report under Appendix C be approved as recommended practice and printed in the Manual, and the subject continued.

(4) That Appendix D be received as information and the subject discontinued.

(5) That the report under Appendix E be approved as recommended practice and printed in the Manual, and the subject discontinued.

(6) That Appendix F be received as information and the subject continued.

(7) That the report under Appendix G be approved as recommended practice and printed in the Manual and the subject discontinued.

(8) That Appendix H be accepted as information and the subject continued.

(9) That Appendix I be accepted as information and the subject discontinued.

(10) That Appendix J be accepted as information and the subject continued.

(11) That Appendix K be accepted as information and the subject continued.

Progress is reported on subjects C–2, F–1, F–4.

Respectfully submitted,

The Committee on Records and Accounts,

C. C. Haire, *Chairman.*

Appendix A

(A–1) REVISION OF MANUAL

D. W. Smith, Chairman, Sub-Committee; E. S. Butler, W. L. Foster, J. H. Hande, A. T. Hopkins, P. R. Leete, W. M. Ludolph, E. W. Metcalf.

The Committee recommends for adoption by the Association the following revisions:

Present Form	*Proposed Form*
Pages 726 and 727, *paragraphs* 6 and 7 near bottom of page.	
(e) Equipment Completion Report. Form 1118.	
Specifications for Form 1118. Form as shown. Size 11 × 17 inches. All lines and printing black.	
Instructions for Use of Form 1118. A report must be prepared on this form for each equipment project by the designated officer, as soon after completion as possible, listing and describing the units of equipment affected and giving careful description of the changes made and listing the units involved, both added and retired, with the cost of each. If a project involves changes in a number of units completed in more than one six months' period	Omit

Present Form	*Proposed Form*
a progress report should be made covering the changes completed in each six months' period. When the whole project is finished a final report should be prepared covering all the changes made under A.F.E., which will be a summary of all the semi-annual progress reports.	Omit

Present Form	*Proposed Form*
7. Labor and General Forms. (a) Time Roll. Form 1119. Specifications for Form 1119. Form as shown. Size of book, 5½ × 8½ inches. Cover to be of three-ply manila paper, book proper to be on yellow paper; printing to be in black. Book to contain 12 pages. Form shown is reduced size.	
Page 758, *paragraph* 4. Carriers are constantly striving to get the maximum worth of the maintenance dollar. They should be able to show that their expenses are efficiently and economically handled as a matter of sound business practice, but since the passage of the Transportation Act, 1920, it is essential that this information be readily available in handling matters with the Government pertaining to the recapture clause of this Act.	Carriers are constantly striving to get the maximum worth of the maintenance dollar. They should be able to show that their expenses are efficiently and economically handled as a matter of sound business practice.

Appendix B

(A–2) BIBLIOGRAPHY ON SUBJECTS PERTAINING TO RECORDS AND ACCOUNTS

A. P. Weymouth, Chairman, Sub-Committee; E. V. Braden, C. K. Smith, H. J. Stroebel, D. C. Teal, W. H. Woodbury.

The method followed in compiling this bibliography for the current year is similar to that used in previous years. Each member was assigned certain periodicals to review and report on important articles, and any new books of interest.

The following is respectfully submitted as a bibliography review covering the period from November, 1932, to October, 1933, inclusive.

BIBLIOGRAPHY

I—Books

The Coordination and Development of Transport; Final Report by the British Royal Commission presented December, 1930. Henry Sotheran, Ltd., London, England.

Public Utility Regulation. By Wm. Mosher and Finla G. Crawford. Harper and Bros., June, 1933.

Railway Operations for 1932. Special Series No. 59, Bureau of Railway Economics, May, 1933.

Electrification of Steam Railways. Sixth Report of Electrification. Committee of National Electric Light Assoc. (Publication 247), May, 1933.

Railroads of Brazil, public and private operation of railways. By Julian S. Duncan, Columbia University Press, Jan., 1933.

Rate making under present economic conditions. By N. T. Veach, Jr., American Water Works Assoc. Journal, Vol. 25, No. 3, March, 1933.

Value Theory and Business Cycles. By H. L. McCracken, Falcon Press, N. Y., Sept., 1933.

The American Railroad in Laboratory, American Railway Assoc., 1933.

II—Periodicals

(a) General Railway Situation

Railways propose legislative program. Railway Age, December 10, 1932, p. 859.

National Transportation Committee makes report, Railway Age, February 18, 1933, p. 247.

Reorganization law in effect. Railway Age, March 11, 1933, p. 362.

New transportation policies proposed by the National Chamber of Commerce, including changes in railroad regulation. Nation's Business, February, 1933, p. 50.

The railroads' need for a new deal, article by A. B. Barber in Nation's Business, June, 1933, p. 40.

Rail and motor rivals getting together. Comments on and summary of the report of the joint committee of railway and highway users. Literary Digest, Feb. 18, 1933, p. 40.

Congress passes Railroad Bill, the Emergency Railroad Transportation Act 1933, providing for a Federal Coordinator, revision of the rule of rate-making, repeal of recapture provisions, and reduction in valuation work. Railway Age, June 17, 1933, p. 865.

Rail relief by Co-ordination, introducing Mr. Eastman to his new job as Federal Coordinator of Railroads, Literary Digest, June 17, 1933, p. 6.

Speeding up the Railroads. The Federal Coordinator seeks to unify the National Transportation System. Article by Lawrence Sullivan, Literary Digest, October 14, 1933, p. 5.

(b) Valuation

Interstate Commerce Commission plans to make valuation records current. Statement of Commissioner Lewis before annual convention of National Assoc. R. R. and Pub. Utility Commissioners, Railway Age, November 26, 1932, p. 740.

The Interstate Commerce Commission on December 17, 1932, issued six orders pertaining to the modification, suspension and cancellation of valuation orders. Railway Age, December 31, 1932, p. 991.

A decision of the Supreme Court, rendered May 8, 1933, in the case of Los Angeles Gas & Electric Corp. vs. R.R. Commission of the State of California discussed at some length principles of valuation and methods for determination of rate base. Case was referred back to District Court for review and report.

(c) Accounting

The Supreme Court of the U. S., in a decision rendered November 7, 1932, sustained the validity of an order of the I.C.C. requiring the N. & W. Ry. to carry certain coal mine properties on its books as "Miscellaneous Physical Property" instead of transferring them to the Road & Equipment account. Ry. Age, Nov. 12, 1932, p. 687.

I.C.C. ruling in connection with rebuilding of freight cars, Accounting for same as additions. Traffic World, Jan. 14, 1933, p. 58.

Improved car accounting and statistics at lower costs is reported by Boston & Maine R.R. with punch card equipment. Railway Age, April 15, 1933, p. 548.

B. & O. R.R. changes depreciation basis for equipment from a "service mile" basis to a percentage of ledger value, in order to conform to a criticism of the I.C.C. Railway Age September 16, 1933, p. 417.

Coordinator Eastman announced the appointment of a committee to investigate the subject of railroad cost-finding and the possibility of introducing new accounting and statistical methods. Railway Age, September 23, 1933, p. 446.

(d) Foreign

Report of Special Committee Appointed to Investigate and Report on Certain Specific Questions Relating to The Capital Indebtedness of the Victorian Railways, 1933. H. J. Green, Government Printer, Melbourne, Australia.

Appendix C

(B–1) DRAWING AND DRAFTING ROOM PRACTICE

D. L. Avery, Chairman, Sub-Committee; A. M. Blanchard, R. R. L. Bullard, V. H. Doyle, W. L. Foster, C. A. Knowles, W. M. Ludolph, D. W. Smith, D. C. Teal, G. R. Walsh, A. P. Weymouth.

The Committee devoted most of its time during the year preparing a pamphlet covering Electrical and Signal Symbols. At the request of Committees X—Signals and Interlocking and XVIII—Electricity, it was decided to discontinue work pertaining to their symbols.

Last year's report of the Committee has been revised to include constructive suggestions and additions offered during the year.

Action Recommended

It is recommended that the report be approved for publication in the Manual.

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BRIDGE RIVETS	12
BRIDGES	6
BUILDINGS AND STRUCTURES	4
CARTOGRAPHY	3
CULVERTS, SEWERS, ETC.	6
ELECTRIFIED LINES	7
FENCES	5
FIRE PREVENTION	7
HEAT-POWER APPARATUS	14-15
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LINES-BOUNDARY AND SURVEY	3
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MATERIALS-ENGINEERING-METALS	10
MATERIALS-ENGINEERING-MINERALS	11
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OIL AND GAS	6
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RAILWAY TRACKS—TRACK MAPS	2
RAILWAYS TOPOGRAPHICAL MAPS	2
RELIEF	1
REFRIGERATION	17
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WIRES — POLE LINE	7

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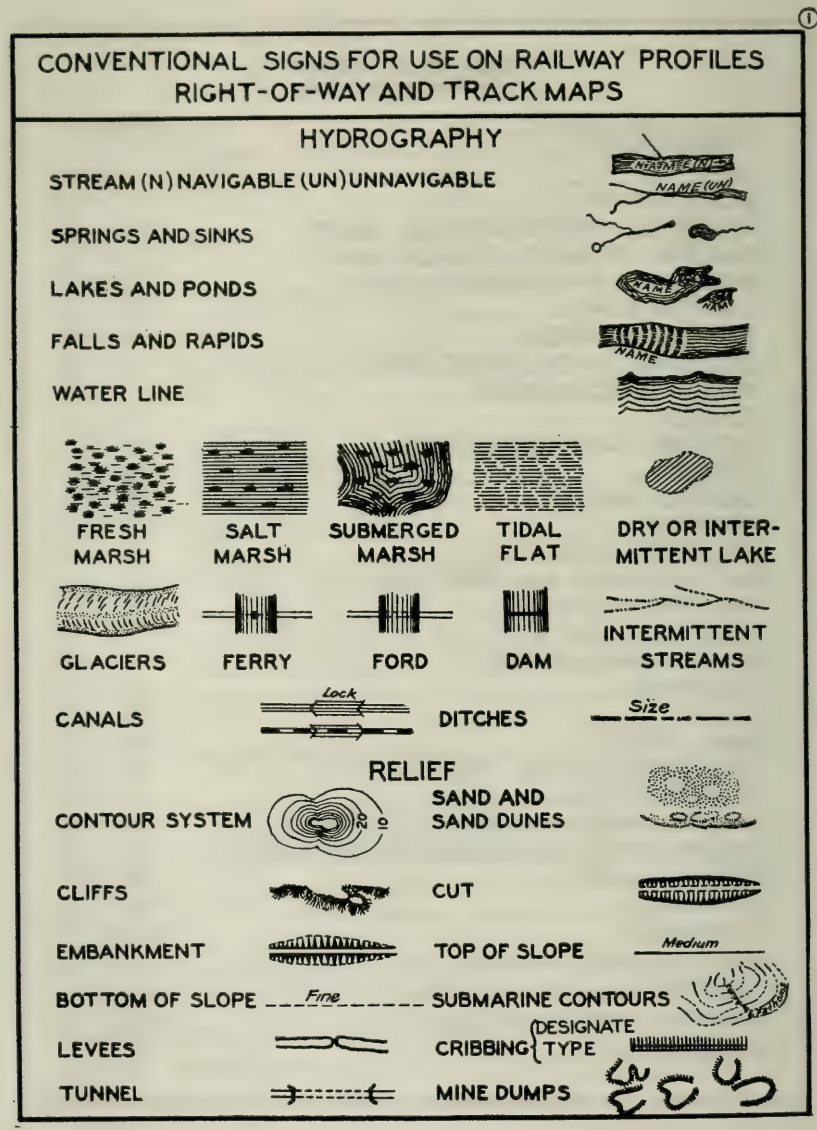

CONVENTIONAL SIGNS FOR USE ON RAILWAY PROFILES
RIGHT-OF-WAY AND TRACK MAPS
HYDROGRAPHY
STREAM (N) NAVIGABLE (UN) UNNAVIGABLE
NAME (N)
NAME (UN)
SPRINGS AND SINKS
LAKES AND PONDS
NAME
FALLS AND RAPIDS
NAME
WATER LINE
FRESH MARSH
SALT MARSH
SUBMERGED MARSH
TIDAL FLAT
DRY OR INTERMITTENT LAKE
GLACIERS
FERRY
FORD
DAM
INTERMITTENT STREAMS
CANALS
Lock
DITCHES
Size
RELIEF
CONTOUR SYSTEM
20
SAND AND SAND DUNES
CLIFFS
CUT
EMBANKMENT
TOP OF SLOPE
Medium
BOTTOM OF SLOPE
Fine
SUBMARINE CONTOURS
LEVEES
CRIBBING
DESIGNATE TYPE
TUNNEL
MINE DUMPS

②

HILL SHADING

TAILINGS OR MINING DEBRIS

DEPRESSION CONTOURS

ABUTMENT, WALL AND PIER

AGRICULTURE

MEADOW

CLEARED LAND

DECIDUOUS TREES

ORCHARD

OAK TREES

EVERGREEN TREES

WILLOWS

PINE, WILLOWS AND BRUSH

CORN

TOBACCO

VINYARD

CULTIVATED LAND

*RAILWAYS (TOPOGRAPHICAL MAPS)

STEAM

ELECTRIC

STREET RAILWAY

NARROW GAUGE

* RAILWAY TRACKS (TRACK MAPS)

RAILWAY TRACK OR OLD TRACK TO REMAIN — X

OLD TRACK TO BE TAKEN UP — X

PROPOSED TRACKS — (RED)

PROPOSED FUTURE TRACKS — (RED)

FOREIGN TRACKS — (COLOR OTHER THAN RED OR BLACK WITH INITIALS OF RD.)

X-FOR NEW OR SPECIAL MAPS MADE FOR A SPECIFIC PROJECT.

ALIGNMENT-4°CURVE TO RIGHT-2°LEFT — 4°C.R. 2°C.L.

ALIGNMENT-2°CURVE LEFT-250'SPIRAL — 250'S. 2°C.L. 250'S.

PROFILES-VERTICAL CURVES — +0.1% +0.3% -0.2% -0.05% V. C.

* INDICATES USE OF SINGLE OR DOUBLE LINES FOR RAILWAY TRACK AND YARD STUDIES. DOUBLE LINES ARE SATISFACTORY FOR SCALES OF 1" EQUALS 50' OR LARGER. SINGLE LINE SHOULD BE USED FOR SMALLER SCALES. LINES MAY BE LEFT UNCOLORED.

③

BOUNDARY AND SURVEY LINES

FOREIGN R. OF W. LINE
STATE LINE
COUNTY LINE
TOWNSHIP LINE
CITY OR VILLAGE LINE
RESERVATION LINE
LAND GRANT LINE
STREET BLOCK OR OTHER PROPERTY LINE
SURVEY LINE — RED
CENTER LINE — Original (Track Or Section) Center Line 19. If Monumented, Show Location And Proper Symbol.
COMPANY PROPERTY R. OF W. LINE
FENCE (ON STREET LINE)
FENCE ON RAILWAY PROPERTY LINE

CARTOGRAPHY

SECTION CORNER — 17 16 / 20 21
SECTION CENTER
TRIANGULATION STATION OR TRANSIT POINT
BENCH MARK — B.M. X 1232
STONE MONUMENT
IRON MONUMENT
CITY
VILLAGE
CITY LIMITS
FIRE LIMITS
CEMETERIES — CEM.
CHURCH-SCHOOL
COKE OVENS
TANKS AND OIL RESERVOIRS
OIL AND GAS WELLS
MINE OR QUARRY
PROSPECT
SHAFT
MINE TUNNEL
LIGHTHOUSE OR BEACON
COAST GUARD STATION — L.S.S. — C.G.S.

MAGNETIC MERIDIAN — N — Variation Angle
★ HATCH OR COLOR (TRANSPARENT) RED

④

TRACK FIXTURES

TURNOUT AND SWITCH STAND

INTERLOCKED SWITCH

DOUBLE SLIP SWITCH

SINGLE SLIP SWITCH

DERAIL (LIFT TYPE) (SWITCH POINT)

BUMPING POST

SKATE MACHINES
POWER OPERATED
MANUALLY OPERATED

CAR RETARDER
SINGLE
DOUBLE

CROSSING

* BUILDINGS AND STRUCTURES

STONE [S] FRAME [F] BRICK [B]
CONCRETE [C] CORRUGATED IRON [C.I.] BRICK PASS. STA. [B.P.]
ELECTRICAL SUB-STATION [S.S.] LIGHTNING ARRESTER HOUSE [L.A.]
INDICATE USE AND NUMBER OF STORIES.

PLATFORM OR DRIVEWAY (INDICATE KIND AND CHARACTER)

TURNTABLE INTERLOCKING TOWER

ASH PIT [A.P.] COALING STATION (MECHANICAL) [C.S.]

COALING STA. (TRESTLE) [C.S.] CIRCULAR ENGINE HOUSE

(5)

RECTANGULAR ENGINE HOUSE (Indicate Kind And Character)

SECTION HOUSE — PRIVY

SECTION TOOL HOUSE — GRAIN ELEVATOR G.E.

* INDICATE TYPE AND CONSTRUCTION BY COMBINATION OF LETTERS.

TRACK ACCESSORIES

RAIL REST — GANTRY CRANE

MAIL CRANE — BOOM CRANE

GAS CONTAINER G.C. — TRACK PAN

TRACK SCALES (Indicate Capacity And Length) — WAGON SCALES

* FENCES *(GIVE HEIGHT OF FENCE)

STONE FENCE — BOARD FENCE

PICKET FENCE — BARB WIRE FENCE

RAIL FENCE — WORM FENCE

WOVEN WIRE FENCE — SNOW FENCE

SNOW SHED — HEDGE

PROPERTY LINE NOT FENCED

STOCK PENS — INTER TRACK FENCE

HIGHWAYS AND CROSSINGS

PUBLIC AND MAIN ROADS (SHOW STATE OR U.S. ROUTE NO)

PRIVATE AND SECONDARY ROADS

TRAILS

STREET AND PUBLIC ROAD CROSSINGS

PRIVATE ROAD CROSSING

ROAD CROSSING AT GRADE

" " UNDER "

" " OVERHEAD

CROSSING GATE

TURNSTILE

CATTLE GUARD

FARM GATE

(6)

MINES

TUNNEL — SHAFT

TEST OPENING — COAL OUTCROP

MINE IN OPERATION

OIL AND GAS SYMBOLS

LOCATION, RIG OR DRILLING WELL — SALT WELL

OIL WELL — SMALL OIL WELL

DRY HOLE — DRY HOLE WITH SHOWING OF OIL

GAS WELL — GAS WELL " " " "

SYMBOL OF ABANDONMENT v THUS

NUMBER OF WELLS, THUS 10 3 7 6 4

SHOW VOLUMES, THUS 3M. 7 3M. 3B 2 30B Salt Sand 3 1½ M Injun 6 1B Injun 5

* BRIDGES

D.P. E-70

GIRDER

TRUSS

TRESTLE (WOODEN)

SIGNAL BRIDGE

LIFT SPAN

BASCULE, DOUBLE LEAF

BASCULE, SINGLE LEAF

DRAW SPAN

* USE LETTERS TO DESCRIBE GIRDER AND TRUSS BRIDGES. GIVE LOADING

CULVERTS, SEWERS, ETC.

MASONRY ARCH OR FLAT TOP CULVERT

PIPE (OVER 36" DIA.) Size And Kind

PIPE DRAIN OR WOOD BOX (36" DIA. AND UNDER) Size And Kind

SEWER Size And Kind — CATCH BASIN C.B.

MANHOLE M.H. — SUMP Sump

(INDICATES DIRECTION OF FLOW →)

7

WATER SUPPLY AND PIPE LINES

WATER TANK (GIVE CHARACTER DIAM. HEIGHT CAP. IN GALS.) W.T.

WATER COLUMN (GIVE SIZE AND TYPE)

COMPANY (WATER PIPE)

OTHER WATER PIPE

GAS LINE

STEAM LINE

OIL LINES

COMPRESSED AIR

(GIVE SIZE AND KIND OF PIPE AND DIRECTION OF FLOW)

VALVE (INDICATE SIZE) V

RISER R

METER (NAME AND SIZE) M

FIRE PREVENTION

FIRE HYDRANT (SHOW SIZE, NO. OF HOSE AND STEAMER CONNS.) H

FIRE ALARM BOX F.A.

CHECK VALVE (ARROW IN DIRECTION OF FLOW)

WALL REEL OR HOSE RACK

HOSE AND HYDRANT HOUSE

FIRE DEPT. CONNECTION

AUTOMATIC SPRINKLER A.S.

CHEMICAL FIRE EXTINGUISHER { HAND OR WHEEL / CARRIAGE

POST INDICATOR VALVE

POLE LINE WIRES

POWER TRANSMISSION, SIGNAL, TELEGHAPH AND TELEPHONE LINES. (DESIGNATE WIRES AND OWNERSHIP)

ELECTRIFIED LINES

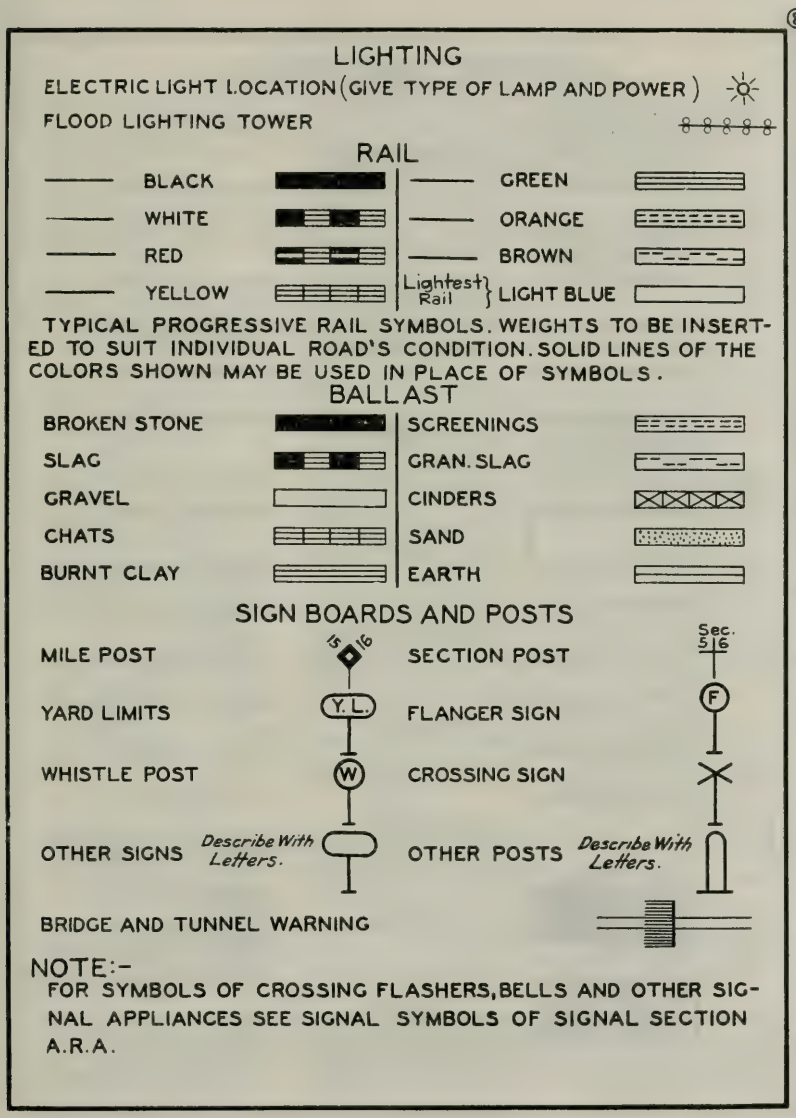
THIRD RAIL — Running Rail Or C.L. Of Track

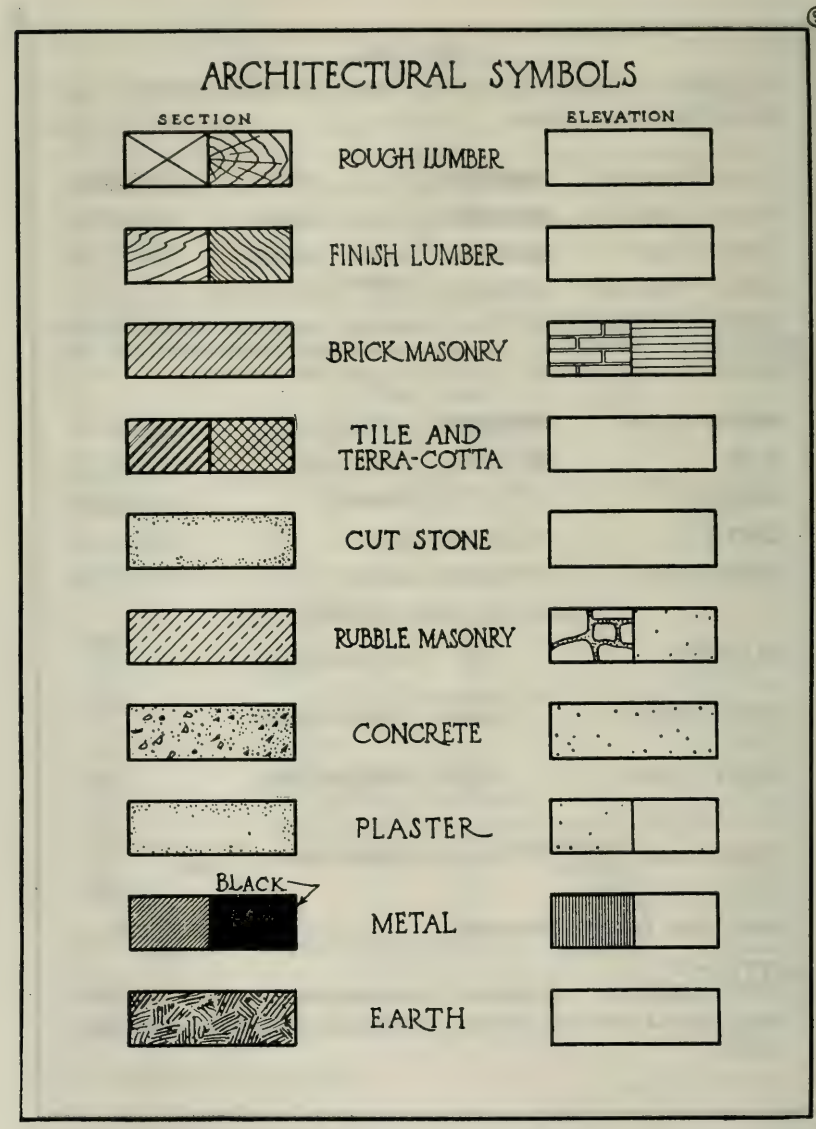
JUMPERS — Running Rail Or C.L. Of Track — Running Rail

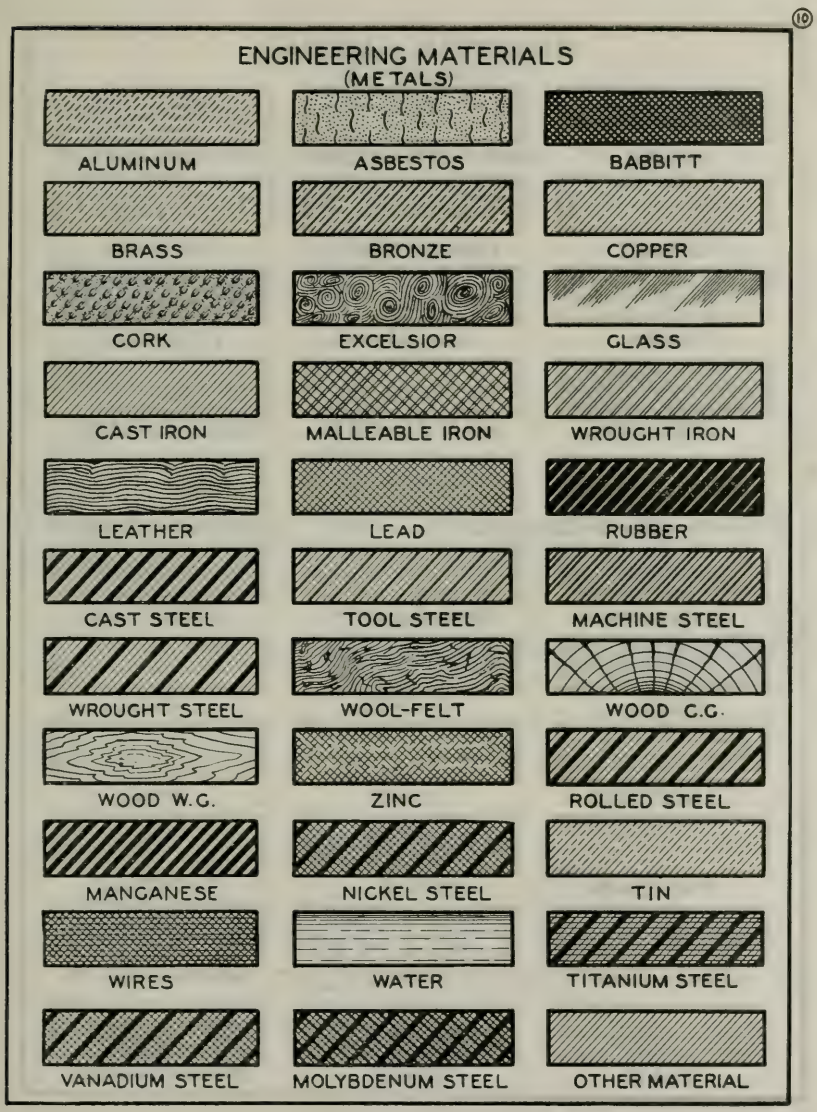
FEEDER — Feeder — Third Rail

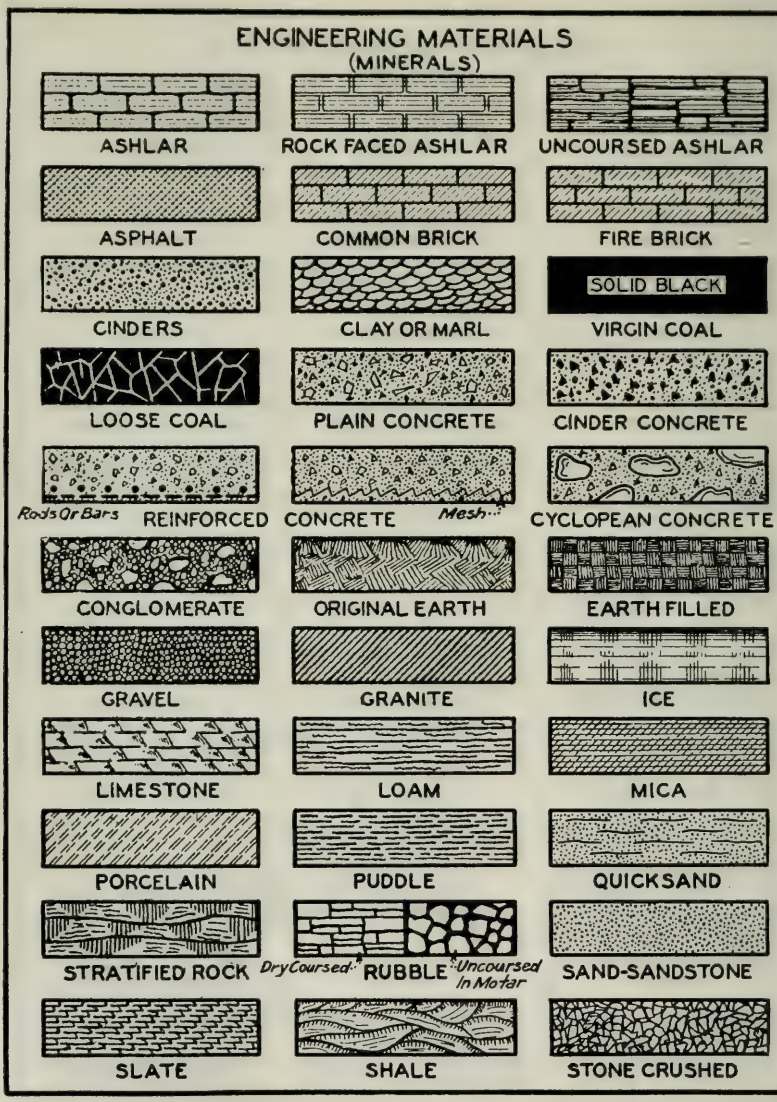
SWITCH

OVERHEAD RAIL OR WIRE — State Kind


8
LIGHTING
ELECTRIC LIGHT LOCATION (GIVE TYPE OF LAMP AND POWER)
FLOOD LIGHTING TOWER
RAIL
BLACK
WHITE
RED
YELLOW
GREEN
ORANGE
BROWN
Lightest Rail
LIGHT BLUE
TYPICAL PROGRESSIVE RAIL SYMBOLS. WEIGHTS TO BE INSERTED TO SUIT INDIVIDUAL ROAD'S CONDITION. SOLID LINES OF THE COLORS SHOWN MAY BE USED IN PLACE OF SYMBOLS.
BALLAST
BROKEN STONE
SLAG
GRAVEL
CHATS
BURNT CLAY
SCREENINGS
GRAN. SLAG
CINDERS
SAND
EARTH
SIGN BOARDS AND POSTS
MILE POST
15 16
SECTION POST
Sec. 5 6
YARD LIMITS
Y. L.
FLANGER SIGN
F
WHISTLE POST
W
CROSSING SIGN
OTHER SIGNS
Describe With Letters.
OTHER POSTS
Describe With Letters.
BRIDGE AND TUNNEL WARNING
NOTE:-
FOR SYMBOLS OF CROSSING FLASHERS, BELLS AND OTHER SIGNAL APPLIANCES SEE SIGNAL SYMBOLS OF SIGNAL SECTION A.R.A.

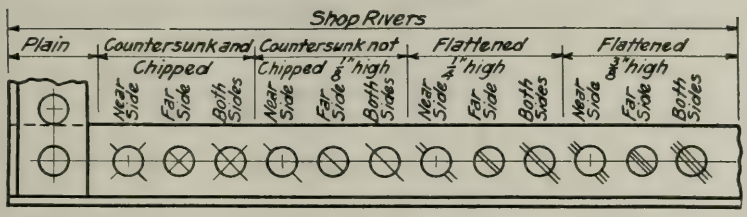

ARCHITECTURAL SYMBOLS
SECTION
ELEVATION
ROUGH LUMBER
FINISH LUMBER
BRICK MASONRY
TILE AND TERRA-COTTA
CUT STONE
RUBBLE MASONRY
CONCRETE
PLASTER
BLACK
METAL
EARTH

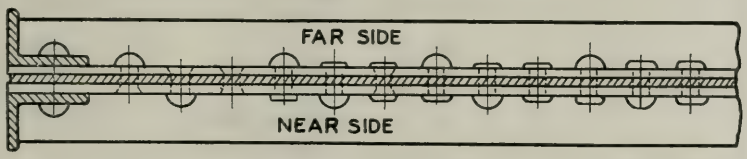

10
ENGINEERING MATERIALS
(METALS)
ALUMINUM
ASBESTOS
BABBITT
BRASS
BRONZE
COPPER
CORK
EXCELSIOR
GLASS
CAST IRON
MALLEABLE IRON
WROUGHT IRON
LEATHER
LEAD
RUBBER
CAST STEEL
TOOL STEEL
MACHINE STEEL
WROUGHT STEEL
WOOL-FELT
WOOD C.G.
WOOD W.G.
ZINC
ROLLED STEEL
MANGANESE
NICKEL STEEL
TIN
WIRES
WATER
TITANIUM STEEL
VANADIUM STEEL
MOLYBDENUM STEEL
OTHER MATERIAL

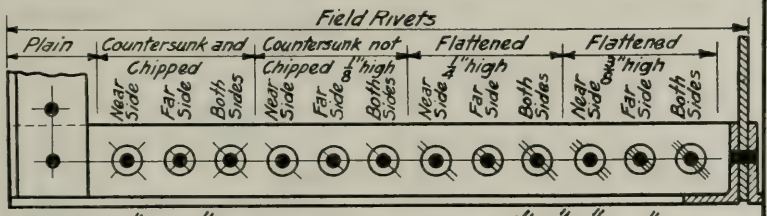

ENGINEERING MATERIALS
(MINERALS)
ASHLAR
ROCK FACED ASHLAR
UNCOURSED ASHLAR
ASPHALT
COMMON BRICK
FIRE BRICK
CINDERS
CLAY OR MARL
SOLID BLACK
VIRGIN COAL
LOOSE COAL
PLAIN CONCRETE
CINDER CONCRETE
Rods Or Bars
REINFORCED
CONCRETE
Mesh
CYCLOPEAN CONCRETE
CONGLOMERATE
ORIGINAL EARTH
EARTH FILLED
GRAVEL
GRANITE
ICE
LIMESTONE
LOAM
MICA
PORCELAIN
PUDDLE
QUICKSAND
STRATIFIED ROCK
Dry Coursed
RUBBLE
Uncoursed In Mortar
SAND-SANDSTONE
SLATE
SHALE
STONE CRUSHED

(12)

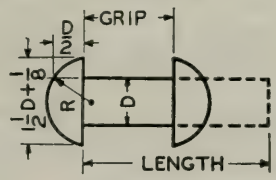
⊕ A-BRIDGE RIVETS

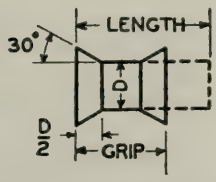






NOTE:- $\frac{1}{2}''$ AND $\frac{5}{8}''$ RIVETS TO BE FLATTENED $\frac{1}{4}''$. $\frac{3}{4}''$-$\frac{7}{8}''$ AND 1" RIVETS TO BE FLATTENED $\frac{3}{8}''$.





▲ B-STRESSES

+ TENSION — COMPRESSION

13

PLUMBING SYMBOLS

CORNER TUB

BUILT IN TUB

ROLL RIM TUB

SHOWER STALL

SHOWER HEAD

S

OVERHEAD GANG SHOWER

PEDESTAL LAVATORY

P.L.

WALL LAVATORY

W.L.

CORNER LAVATORY

PLAIN KITCHEN SINK

K.S.

KITCHEN SINK R.&L. DRAIN BOARD

KITCHEN SINK L.H. DRAIN BOARD

COMBINATION SINK AND DISHWASHER

COMBINATION SINK AND LAUNDRY TRAY

SLOP SINK

WASH SINK WALL TYPE

WASH SINK

WATER CLOSET (HIGH TANK)

WATER CLOSET (LOW TANK)

WATER CLOSET (NO TANK)

URINAL (PEDESTAL TYPE)

PU

URINAL (WALL TYPE)

URINAL (STALL TYPE)

URINAL (TROUGH TYPE)

T U

DRINKING FOUNTAIN (PEDESTAL TYPE)

DF

DRINKING FOUNTAIN (WALL TYPE)

DF

(14)

PLUMBING SYMBOLS

LAUNDRY TRAY — L T

HOT WATER TANK — HWT

WATER HEATER — WH

WASHING MACHINE — WM

HOSE BIB — HB

GAS OUTLET — G

DRINKING FOUNTAIN (TROUGH TYPE) — DF

VACUUM OUTLET

DRAIN — D

GREASE SEPARATOR — G

OIL SEPARATOR — O

CLEANOUT — C/O

HEAT-POWER APPARATUS SYMBOLS

STEAM PIPE CONNECTION

CONDENSATE PIPE CONNECTION

WATER PIPE CONNECTION

AIR PIPE CONNECTION

PIPE CONNECTION

CROSS SECTION, NO CONNECTION, PIPES CROSSING

STEAM GENERATOR (BOILER)

FLUE GAS REHEATER (INTERMEDIATE SUPERHEATER)

LIVE STEAM SUPERHEATER

FEED HEATER WITH AIR OUTLET

STEAM TURBINE

SURFACE CONDENSER

THREE-PHASE GENERATOR

(15)

CONDENSING TURBINE

OPEN FEED TANK

CLOSED FEED TANK

AUTOMATIC REDUCING VALVE

AUTOMATIC BYPASS VALVE

AUTOMATIC VALVE OPERATED BY GOVERNOR

BOILER FEED PUMP

DYNAMIC PUMP (AIR EJECTOR)

HEATING AND VENTILATING SYMBOLS

LOCK SHIELD VALVE

REDUCING VALVE

DIAPHRAGM VALVE

DIAPHRAGM VALVE STEM PERPENDICULAR

THERMOSTAT

RADIATOR TRAP (ELEVATION)

RADIATOR TRAP (PLAN)

COLUMN RADIATOR (PLAN)

COLUMN RADIATOR (ELEVATION)

WALL RADIATOR (PLAN)

WALL RADIATOR (ELEVATION)

PIPE COIL (PLAN)

PIPE COIL (ELEVATION)

INDIRECT RADIATOR (PLAN)

INDIRECT RADIATOR (ELEVATION)

SUPPLY DUCT (SECTION)

EXHAUST DUCT SECTION

UNIT HEATER U.H.

BUTTERFLY DAMPER PLAN (OR ELEVATION)

(16)

BUTTERFLY DAMPER ELEVATION OR PLAN		VANES	
DEFLECTING DAMPER SQUARE PIPE		AIR CONDITIONER	A. C.
AIR SUPPLY OUTLET		EXHAUST OUTLET	

PIPE AND PIPE FITTINGS SYMBOLS

	FLANGED	SCREWED	BELL & SPIGOT
PIPE			
JOINT			
ELBOW 90 DEG.			
ELBOW 45 DEG.			
ELBOW-TURNED UP			
ELBOW-TURNED DOWN			
ELBOW-LONG RADIUS			
SIDE OUTLET ELBOW-OUTLET DOWN			
SIDE OUTLET ELBOW OUTLET UP			
BASE ELBOW			
DOUBLE BRANCH ELBOW			
REDUCING ELBOW			

(17)

	FLANGED	SCREWED	BELL & SPIGOT
TEE			
TEE-OUTLET UP			
TEE-OUTLET DOWN			
SIDE OUTLET TEE-OUTLET UP			
SIDE OUTLET TEE-OUTLET DOWN			
CROSS			
REDUCER			
LATERAL			
VALVE			
CHECK VALVE-TRIANGLE IN DIRECTION OF FLOW			
ANGLE VALVE			
EXPANSION JOINT			
REDUCING FLANGE			
UNION			
SLEEVE			

REFRIGERATION

ELECTRIC REFRIGERATOR [E.R.] GAS REFRIGERATOR [G.R.]

ICING MACHINE [I.M.]

Appendix D

(B–2) JOINT FACILITY RECORDS

(a) Appraisal methods and records for keeping up-to-date.
(b) Maintenance and operation reports and records.
(c) Effect of depreciation accounting.

B. A. Bertenshaw, Chairman, Sub-Committee; Anton Anderson, D. L. Avery, E. V. Braden, E. S. Butler, James Erskine, W. L. Foster, C. C. Haire, J. H. Hande, G. R. Walsh.

General

It is common practice where facilities are owned by one railroad and jointly used by one or more other railroads to cover the use, maintenance and operation of the jointly used facilities by formal contract or agreement. There is at present a trend toward the elimination of duplicate facilities and the unification of small differently owned properties into a larger operating unit, which will largely increase the number of Joint Facility Agreements and make desirable any methods and forms which will enable the railroads to easily maintain records of changes in the jointly used property and to assist in their performance according to the agreement.

(a) Appraisal Methods and Records for Keeping Up-to-Date

In Joint Facility contracts the using company usually agrees to pay to the owning company a rental for the use of the joint facilities. This rental is usually a specific per cent per annum on a rental base or sum of money agreed upon at the time the agreement is executed. The determination of this rental base is in most cases subject to prolonged negotiation, and various methods and records are used to assist in fixing the sum finally agreed upon. The Committee has made a study of the different ways of arriving at the rental base, and found the following have been most commonly used:

1. Appraised value agreed to by interested parties.
2. Ledger value or original cost.
3. Estimated original cost.
4. Cost of reproduction.
5. I.C.C. Valuation (Tentative or Final).

There are so many modifying factors to be taken into consideration that no ironclad rule or formula for arriving at the rental base is practical. Some of the factors to be considered in arriving at a rental base are:

1. Age of property.
2. Condition as regards maintenance and depreciation.
3. Fluctuating costs affecting value.
4. Local conditions.
5. Different capacity requirements of interested parties.

Regardless of which method is used in deriving the figures to be used in the negotiations, the basis should be an inventory of the property under consideration. This inventory may be readily obtained for property in existence on Date of Valuation of the owner by taking the field inventory of the Bureau of Valuation and adjusting it for subsequent changes from an inspection of the property and Valuation Order No. 3 records; for property constructed since Valuation Date the inventory is easily obtained from Construction and Valuation Order No. 3 records.

If the ledger value or original cost is known, and it is decided to use this as a basis for negotiation, there remains only the application of original costs to the inventory. If some other basis is to be used, then unit prices as of some selected period or level may be applied to the inventory (for this purpose the most readily available are those

used by the Bureau of Valuation for the period 1910–1914) and the necessary adjustments made by use of index numbers; further adjustments may then be made for depreciation or other modifying factors.

The rental base as finally agreed upon is often neither the exact ledger value nor the sum developed by the owner prior to the negotiations as representing the value of the property. In such cases each unit or item of the inventory should be apportioned its pro rata share of the rental base.

The rental base having been determined, provision must be made to keep this base up to date, due to changes in the property from time to time. Different methods have been used for this purpose, the most common of which are:

1. By adding the net expenditures chargeable to Capital Account as reflected in the accounting records.
2. By maintaining a detail of the original appraisal with additions and retirements, and retiring therefrom items that can be identified, or equitably estimated portions thereof, at the amount included in such detail for the property retired.
3. In case of retirements, retire from the rental base the percentage which the property retired bears to the total.

As stated above, the rental base is seldom the same amount as that carried in the accounting records of the owning company for the property jointly used, so that if, when any of the property is retired, the rental base is adjusted by deducting the same amount as is retired from the owner's books, an improper amount may be deducted, and over a period of time, with frequent changes in the property, the rental base will become considerably distorted. Furthermore, where property is added, the owning company usually adds more to the rental base in the way of percentages for overhead, supervision, etc., than it adds to its own capital structure; this increase should also be deducted from the rental base for corresponding retirements.

In fairness to both owner and user, records should be kept that will show

1. That portion of the rental base assignable to each unit of property as of the date of the agreement.
2. Additions—Amount lodged in the accounting records of owner and amount added to rental base.
3. Retirements—Amount retired from books of owner and amount retired from rental base.

The nature and extent of jointly used properties, carrier organization and method of handling joint facility bills vary to such an extent as to make it impractical to design a form for uniform use. The property may consist of anything from a single structure, sidetrack, or piece of single main track without appurtenances to a long stretch of multiple main track road with all appurtenances. The Committee presents as Exhibit A a form 11″ × 17″, with columnar headings under which to record pertinent information for keeping the rental base up-to-date.

In column headed "Item" is to be listed the items included in the property as of the date of the agreement, leaving space for subsequent addition of similar items. The extent of the jointly used property, and consequently the bulk of the record, will determine the amount of detail to be recorded. For example, if the jointly used property is relatively small and of a single nature, such as a single main track or a few yard and sidetracks, or a single structure, a complete detail of ties, rail, track fastenings, concrete, structural steel, etc., may be listed, but if the property is extensive and of a complex nature it may be desirable to make the items listed composite in nature, such as a complete structure, a complete side or yard track, water station, etc.

After the items have been listed in accordance with the requirements, the proper unit designation is to be recorded in the next column. The following two columns are

EXHIBIT "A"

NORTH & SOUTH R.R.

RENTAL BASE FOR JOINT FACILITIES

SHEET _____ OF _____ SHEETS
LOCATION _____

LINE No.	ITEM	UNIT	RENTAL BASE: NUMBER UNITS	RENTAL BASE: AMOUNT	CHANGES IN RENTAL BASE: A.F.E. _____ COMP REPT. _____ DATE IN OR OUT OF SERVICE _____ DESCRIPTION _____					A.F.E. _____ COMP REPT. _____ DATE IN OR OUT OF SERVICE _____ DESCRIPTION _____					A.F.E. _____ COMP REPT. _____ DATE IN OR OUT OF SERVICE _____ DESCRIPTION _____					LINE No.
					NUMBER UNITS	ADDED: BOOKS	ADDED: RENT-BASE	RETIRED: BOOKS	RETIRED: RENT-BASE	NUMBER UNITS	ADDED: BOOKS	ADDED: RENT-BASE	RETIRED: BOOKS	RETIRED: RENT-BASE	NUMBER UNITS	ADDED: BOOKS	ADDED: RENT-BASE	RETIRED: BOOKS	RETIRED: RENT-BASE	
1				$		$	$	$	$		$	$	$	$		$	$	$	$	1
2																				2
3																				3
4																				4
5																				5
6																				6
7																				7
8																				8
9																				9
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23																				23
24																				24
25																				25

EXHIBIT "B"

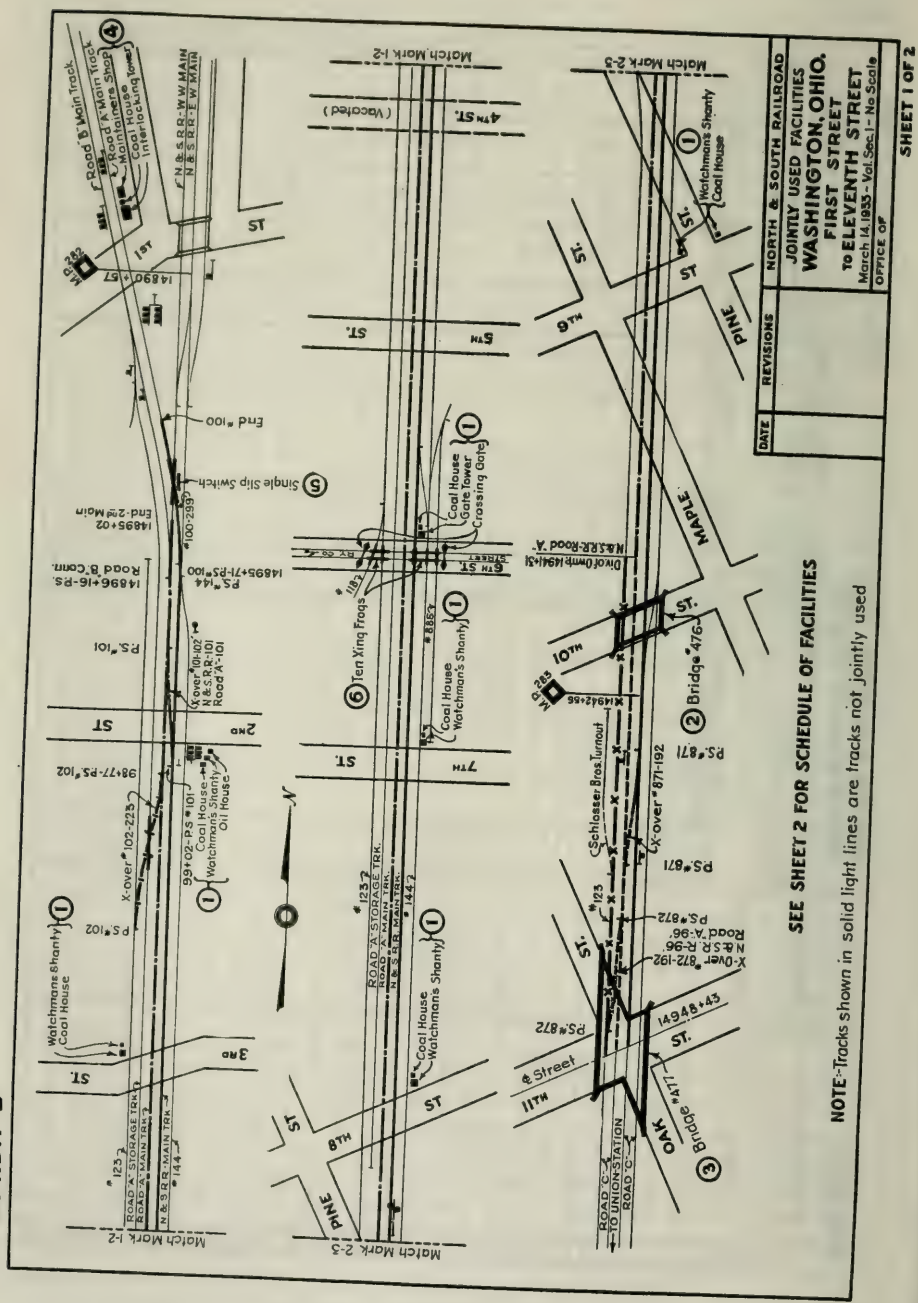
Match Mark 1-2
Match Mark 2-3
Match Mark 2-3
Road "B" Main Track
Road "A" Main Track
Main Switch Shop
Coal House
Interlocking Tower
N.&S.R.R.-W.W. MAIN
N.&S.R.R.-E.W. MAIN
1ST ST.
14890+57
End "100
Single Slip Switch
"100-293"
End-2nd Main
14895+02
14896+16-P.S.
Road B Conn.
14895+71-P.S."100
P.S."144
P.S."101
X over "101-102"
N.&S.R.R.-101
Road A-101
2ND ST
98+77-P.S."102
99+02-P.S."101
Coal House
Watchmans Shanty
Oil House
X-over "102-225
P.S."102
Watchmans Shanty
Coal House
3RD ST.
"123
ROAD A STORAGE TRK.
ROAD A MAIN TRK.
N.&S.R.R. MAIN TRK.
"144
4TH ST. (Vacated)
5TH ST.
6TH ST.
7TH ST.
8TH ST.
PINE
Ten Xing Frogs
"181
"888
Coal House
Watchman's Shanty
Coal House
Gate Tower
Crossing Gate
5TH ST.
STREET
Dir. of Xing 14941+31
N.&S.R.R.-Road "A"
ROAD A STORAGE TRK.
ROAD A MAIN TRK.
N.&S.R.R. MAIN TRK.
"144
"123
Coal House
Watchmans Shanty
Watchmans Shanty
Coal House
6TH ST.
PINE
MAPLE
7TH ST.
10TH ST.
X 14942+55
Bridge "476
P.S."871
Schlosser Bros. Turnout
X-over "871-192
P.S."871
"123
P.S."872
X-Over "872-192
N.&S.R.R.-96
Road "A-96"
P.S."872
14948+43
11TH ST.
& Street
OAK
Bridge "477
ROAD "C"
TO UNION STATION
ROAD "C"
SEE SHEET 2 FOR SCHEDULE OF FACILITIES
NOTE:-Tracks shown in solid light lines are tracks not jointly used
DATE
REVISIONS
NORTH & SOUTH RAILROAD
JOINTLY USED FACILITIES
WASHINGTON, OHIO.
FIRST STREET
to ELEVENTH STREET
March 14, 1933 - Vol. Sec. I - No Scale
OFFICE OF
SHEET 1 OF 2

EXHIBIT "C"

SCHEDULE OF JOINTLY USED FACILITIES ON SHEET 1

KEY	DESCRIPTION OF FACILITIES	OWNERSHIP	MAINTENANCE: IN CHARGE OF	MAINTENANCE: DIVISION OF EXPENSE	OPERATON: IN CHARGE OF	OPERATON: DIVISION OF EXPENSE	CONTRACT: AUDIT NO	CONTRACT: DATE
———	Main Track and Turnouts including Street Surfacing	N & S.R.R.-100%	N.&S.R.R.	N & S.R.R.-100% See Notes 1&2	N.&S.R.R.	N & S.R.R. Roads "A"&"B"-33⅓% each See Notes 3,4 &5	0-38 2540 7236	2-20-1878 5-23-1908 8-1-1924
— — —	Main Track and Turnouts including Street Surfacing	Road "A"-100%	Road "A"	Road "A"-100% See Note 1	N.&S.R.R.	N.&S.R.R. Roads "A"&"B"-33⅓% each See Note 5	0-38 2540 7236	2-20-1878 5-25-1908 8-1-1924
- - - - -	Main Track and Turnouts	N.&S.R.R.-100%	Road "A"	Road "A"-100% See Note 1&2	N.&S.R.R.	N.&S.R.R. Roads "A"&"B"-33⅓% each See Notes 3&4		
—X—	Track #123 and Turnouts Tenth to Eleventh Sts.	Road "A"-100%	N.&S.R.R.	N.&S.R.R.-100% See Notes 1&2	N.&S.R.R.	N.&S.R.R. Roads "A"&"B"-33⅓% each See Notes 3&4		
1	Street Crossing Protection	N&S.R.R.-50% Road "A" 50%	N.&S.R.R.	N.&S.R.R.-33⅓% Roads "A"&"B"-33⅓% each	N.&S.R.R.	N.&S.R.R. Roads "A"&"B"-33⅓% each	7236	8-1-1924
2	Bridge #476-Tenth St.	N&S.R.R.64.84% Road "A"-35.16%	See Note 6	See Notes 1&6	N.&S.R.R.	N.&S.R.R. Roads "A"&"B"-33⅓% each	0-38 2540 7236	2-20-1878 6-23-1908 8-1-1924
3	Bridge #477 — North of ℄ of Eleventh St.	N.&S.R.R.-57.57% Road "A"-42.43%	See Note 6	See Notes 1&6	N.&S.R.R.	N.&S.R.R. Roads "A"&"B"-33⅓% each	0-38 2540 7236	2-20-1878 5-25-1908 8-1-1924
	Bridge #477 — South of ℄ of Eleventh St.	Road "C"-100%	See Note 6	See Note 6	N.&S.R.R.	Road "C"-100%		
4	First Street Interlocking Plant	No Agreement	N.&S.R.R.	N.&S.R.R.-53.58% Road "A"-36.57% Road "B"-9.85%	N.&S.R.R.	N.&S.R.R. Roads "A"&"B"-33⅓% each	2475	9-7-1909
5	Slip Switch at Second St.	N.&S.R.R.-100%	N.&S.R.R.	N.&S.R.R.-50% Road "A"-50% See Note 1	N.&S.R.R.	N.&S.R.R. Roads "A"&"B"-33⅓% each	2340	5-23-1908
—/—/—	X-over #102 at 2nd St. — Turnout in Road "A" Main-75'	N.&S.R.R.-100%	Road "A"	N.&S.R.R.-100%	Road "A"	N.&S.R.R.-100%	2340	5-23-1908
	X-over #102 at 2nd St. — Remaining 148' incl. X-ing Frog	N.&S.R.R.-100%	N.&S.R.R.	N.&S.R.R.-100%	N.&S.R.R.	N.&S.R.R.-100%		
6	10 X-ing Frogs at Sixth St.	N.&S.R.R.-50% St.Ry.Co.-50%	St.Ry.Co.	N.&S.R.R.-50% St.Ry.Co.-50%	St.Ry.Co.	N.&S.R.R.-50% St.Ry.Co.-50%	832	8-17-1895
--------	Turnout to Schlosser Bros Track at Tenth St.	Road "A"-100%	N.&S.R.R.	Road "A"-100%	N.&S.R.R.	Road "A"-100%		

NOTE 1:-Road "B" pays $16600 per year in equal monthly payments, ½ each to N.&S.R.R. and Road "A" for intrest rental, maintenance, depreciation, taxes and insurance.

NOTE 2-N.&S.R.R. maintains all pipe connections and dwarf signals between Tenth and Eleventh Sts and bills Road "A" 50%

NOTE 3:- N.&S.R.R. oils all pipe connections and dwarf signals between Tenth and Eleventh Sts. and bills Road "A" and Road "B" ⅓ each.

NOTE 4:- N.&S.R.R. oils switches of X-over #871 in Eastward Main and X-over #872 in Track #123-Road "B" billed ⅓ and Road "A" not billed-Road "A" oils switches of X-overs #871 and #872 in Westward Main N.S.&R.R. not billed

NOTE 5:-City bills N.S.&R.R. and Road "A" 15% each for expense of Street Lighting at 2nd, 3rd, 6th, 7th, 8th & 9th Sts Each Road then bills Road "B" for ⅓ of its 15%

NOTE 6:-Agreement must be reached in advance as to performance of work and division of expense, see Chief Engineer's Letter of 10-1-31.

DATE	REVISIONS	NORTH & SOUTH RAILROAD
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placed under a general heading of "Rental Base". In column headed "Number Units" is to be recorded the number of designated units included in the rental base, and in the next column, headed "Amount", the pro rata share of the rental base assignable to these units.

Provision is made on this form for three separate changes affecting any item or set of items. Continuation sheets may be used for additional changes. For each change, space is provided at the top of the general division for recording general information, as A.F.E. No., date of change, and a brief general description. There are five columns in which specific information regarding each change is to be shown. The first of these columns is headed "Number Units" and each regular horizontal space on the form has been divided into two spaces in this column. In the upper space will be recorded the number of units added, while in the lower space will be the number of units retired. In the next two columns are to be shown the amounts added in the accounting records and to the rental base respectively, while in the last two columns are shown the amounts deducted due to retirements, first as lodged in the accounting records and next as affecting the rental base. In the case of betterments, due to the fact that the amounts in the books and in the rental base are in effect changed only by the net additional cost of the betterment, no entry will be made in the "retired" columns; only the net additional cost will be shown in the "added" columns. In extensive jointly used properties, or those made up of a large number of small items where it is necessary to adjust the rental base at frequent intervals, it may be desirable to assemble from Exhibit A the amount of the changes in the various items or units and carry the net total change in amount on a separate sheet, but no special form would be necessary in such a case.

(b) Maintenance and Operation Reports and Records

In addition to the usual maintenance and operating records maintained by the owning company in connection with bills rendered against the user, there is a need for some record to be placed in the hands of those responsible for the maintenance and operation of the joint facilities, in order that reports may be originated to bill all expense in accordance with the agreement. This need is emphasized where there are frequent changes in personnel and new employees must become familiar with conditions that have grown up over a number of years, and where various departments handle charges that are finally assembled into a single bill against the user.

Exhibits B and C have been designed to illustrate records setting out the ownership, maintenance and operation of a typical joint facility. These exhibits are each 11″ × 17″ in size, Exhibit B being a plan not drawn to scale, showing the facilities jointly used by means of lines and symbols; the facilities are designated according to ownership, use, maintenance and operation. Exhibit C is a schedule of these same facilities, in which is given a brief description of the various properties according to ownership, use, etc., showing who is in charge of the maintenance and operation, together with the division of the expense of same. There is also a list of contracts and agreements that are applicable to the facilities.

Wherever possible, the schedule of facilities should be placed on the same sheet as the plan, the governing feature being the size of the sheet required to do this. It should not be large enough to make it unwieldy or cumbersome for use in the field. No particular size is recommended, as each road should make a study of the extent of the joint facilities to be taken care of and then adopt a suitable size (multiples of 11″ × 17″ are recommended), as it is very desirable that all be finally placed on sheets that may be conveniently bound in book form.

A study was made in an effort to determine what method is preferable for distinguishing different combinations of ownerships, use, etc. Where the facilities are not

extensive and the layout simple, these various conditions may be represented by using different weights of lines or solid and dashed lines for tracks; other facilities may be numbered or lettered, or a combination of numbers and letters used, and in some instances the schedule of facilities itself may be all that is necessary. But it is the opinion of the Committee that in complicated territory where several distinctions are necessary in the track layout and where the jointly used properties consist of a number of small scattered units such as signals, watchmen's shanties, crossing gates and bells, the additional expense of showing these in different colors is more than compensated for by the ease with which the print may be read and the different facilities located or identified. This is especially desirable in case the plans are placed in the hands of those directly responsible for maintenance and operation, such as supervisors and foremen, for use in the field.

Provision should of course be made to keep these charts up-to-date, else their value will be very largely destroyed. This should be a simple matter if placed in charge of someone who would be notified of all physical changes as well as changes in maintenance and operation. In addition to correcting the subject-matter on each of the charts, the date and nature of the revision should be indicated in a space provided for that purpose, near the title.

(c) Effect of Depreciation Accounting

For many years Federal and certain State regulatory bodies have urged that the railroads adopt a system of depreciation and amortization accounting for their property. This has manifested itself by the Order issued by the Interstate Commerce Commission under Docket No. 15100, Depreciation Charges for Steam Railroad Companies, which, after being made a mandatory order, was suspended.

It has been noted, however, that a few railroads are preparing their contracts in connection with new joint facility agreements so as to anticipate that depreciation accounting will be a requirement. Following are several principal features covering depreciation that are included in certain modern contracts:

1. Provision to include as an operating expense an amount representing depreciation, if and when the I.C.C., or public bodies having jurisdiction in the premises, shall require the accrual thereof.
2. The provision to reduce the capital sum upon which interest is paid as rental by the aggregate amount of any depreciation accruals (less the aggregate amount of charges for retirements).
3. Provisions are made for amortizing the residual capital sum upon which depreciation has not been accrued, in the event the carrier withdraws from the use of the joint facility or any part thereof in accordance with period used as compared to total estimated life.
4. Provisions are made for the future payment periodically, such as monthly, for the proportion of retirement values upon which depreciation has not been accrued, in the event of a large sized retirement.

Conclusions

The Committee is of the opinion that if Joint Facility contracts are made to state specifically how the rental base is to be adjusted, both for additions and retirements, and if records are maintained similar to those outlined above, then not only will billing between roads be less troublesome, but the rendering and checking of joint facility bills will be very much simplified.

The Committee recommends that the report be accepted as information, and the subject discontinued.

Appendix E

(B–3) BRIDGE INSPECTION REPORT FORMS

C. C. Haire, Chairman, Sub-Committee; A. T. Hopkins, F. C. Kane, P. R. Leete, D. W. Smith, G. R. Walsh.

Several progress reports have been made by the Committee during the past several years, but there has not been an unanimity of opinion with the other collaborating committees. This year the forms have been designed so that the five committees are now in accord. There are now included in the Manual two forms for the inspection of bridges: Form 1110, on page 716, for the purpose of general bridge inspection, and Form 1111, on page 718, for the purpose of special inspection. The Manual also contains, pages 847 to 849, inclusive, rules for the inspection of bridges. It is proposed by the Committee that these two forms be superseded by three forms numbered 1110 Rev., 1110–A and 1110–B.

The Committee has given consideration to the practice of many roads, and final conclusion is that these forms should be designed somewhat flexible in nature. The proposed forms are specifically described as follows:

Exhibit No. 1 (Form 1110 Rev.)—Bridge Inspection Report—Covers Masonry, Steel Bridges and Trestles

This form is designed to be filled out and used by the bridge inspector going over the line for each individual masonry, steel bridge or trestle. The size of the form is 5 in. × 9½ in. and can be cut without waste from standard stock. This size will also fit a coat pocket. The sheets may be bound into a book with one or more perforated sheets above each fixed sheet or they may be used in a looseleaf field book. The form can be printed so that a duplicate carbon copy (or a triplicate) can be made for the purpose of furnishing copies to those under whose supervision the maintenance of bridges is performed. The remarks column has been left unruled so that defects found can be referred to in detail. In the same or a separate notebook the inspector can carry a form of similar size, described below:

Exhibit No. 2 (Form 1110–A)—Bridge Inspection Report—Covers Wooden Boxes and Pipe Culverts

This form is the same size as Exhibit 1 and designed for wooden boxes and pipe culverts. It will permit of listing a large number of these minor items on one page and in a like manner Exhibit No. 1 duplicate (or triplicate) carbon copy can be made for filing with interested parties. Some roads may wish to show inspection of masonry boxes and arches on this form instead of on Exhibit No. 1.

Exhibit No. 3 (Form No. 1110–B)—Bridge Inspection Report

Exhibit No. 3, as can be noted, is a summary report which may be compiled from the daily inspection reports. Reports of this kind can be used for any particular period or any series of inspections. It is necessarily a large sized form, 11 in. by 17 in., and the space provided will permit of showing the information for both the inspection forms —namely, Exhibits No. 1 and No. 2.

Action Recommended

The Committee recommends Forms 1110 Rev., 1110–A and 1110–B, together with the explanatory text, for inclusion in the Manual.

5" x 9½"

EXHIBIT No 1

NORTH & SOUTH R.R.

BRIDGE INSPECTION REPORT

Office Of _____

G-Denotes Good Condition F-Fair Condition P-Poor Condition Requires Attention

_____ DIVISION _____ DISTRICT

BRIDGE No. _____ LOCATION _____ LENGTH _____

KIND OF BRIDGE _____ No. OF SPANS _____ HEIGHT _____

Note: Inspector Should Be Familiar With The Rules For Bridge Inspection Contained In The Manual

	Items	Condition	Remarks Or Recommendations
Masonry	Foundations		
	Piers & Abutments		
	Bridge Seats		
	Bench & Wing Walls		
	Arch & Cover Stones		
	Parapet Walls		
	Pointing		
	Riprap		
Girders Or Trusses	Bed Plates & Rollers		
	Lower Flanges Or Chords		
	Upper Flanges Or Chords		
	Web or Diagonals		
	Counters		
	Pins or Rivets		
	Concrete Slabs		
	Line & Camber		
Floor System	Floor Beams & Bearings		
	Connections		
	Reinf. Conc Slab		
	Stringers		
	Connections		
	Hangers		
	Hand Railing & Flooring		
	Ties		
	Footwalk		
	Guard Rail		
	Spacing Timber		
	Drain Holes & Details		
Bracing	Top Laterals		
	Bottom Laterals		
	Sway Frames		
	Portals		
Trestles	Foundations		
	Caps & Stringers		
	Bulkheads		
	Sills		
	Piles & Posts		
	Water Barrels & Ladders		
	Bracing		
	Packing Bolts		
General	Machinery, Movable Spans		
	Vibration & Deflection		
	Approach Track		
	Track On Bridge		
	Paint		
	Date Painted		
	Cleanliness		

Date _____ 19__ Inspector _____

A

5"x 9½"

EXHIBIT No 2

NORTH & SOUTH R.R.

WOOD BOXES & PIPE CULVERTS INSPECTION REPORT

G-Denotes Good Condition F-Fair Condition P-Poor Condition Requires Attention

DIVISION _____ DISTRICT

No	KIND	SIZE	CONDI-TION	REMARKS

Note: Inspector should be familiar with the Rules for Bridge Inspection Contained in the Manual

Date _____ 19__ Inspector _____

EXHIBIT No 3

NORTH & SOUTH RAILROAD

BRIDGE, TRESTLE AND CULVERT INSPECTION REPORT

DIVISION_____ PERIOD_____

FROM_____ TO_____

BRIDGE No.	DESCRIPTION	DATE INSPECTED	CONDITIONS, DESCRIPTION OF WORK REQUIRED ACTION TAKEN AND RECOMMENDATIONS

DATE_____ SIGNED_____

Appendix F

(C–1) STATISTICAL REQUIREMENTS OF OPERATING, ACCOUNTING AND OTHER DEPARTMENTS WITH RESPECT TO MAINTENANCE OF WAY AND STRUCTURES

W. F. Cummings, Chairman, Sub-Committee; Anton Anderson, D. L. Avery, E. V. Braden, W. L. Foster, W. E. Gardner, W. R. Kettenring, J. R. Leguenec, Jr., W. M. Ludolph, W. S. McFetridge, C. K. Smith, C. R. Smith, F. X. Soete, A. P. Weymouth.

This Committee is progressively studying and reporting as to forms and data outlined on the Chart of Accounting and Statistical Report Procedure in Maintenance of

NORTH & SOUTH RAILROAD COMPANY
M. of W. & S. — DEPT.
RECAPITULATION AND DISTRIBUTION OF MATERIAL
— — — — — — — — SECTION
— — — — — — — — DISTRICT
— — — — — — — — DIVISION

(SIZE OF SHEET 11" x 17")

MATERIAL - USED - REMOVED — Nelson — STATE — Nevada — MONTH OF January — 1932

Date	Acct.	Sec.	10"x12" Ft.	12"x12" Pcs.	8"x16" Pcs.	A Cu.	B Cu.	C Cu.	85# Lbs.	85# Ft.	85# Pcs.	85# Cu.	Spikes Kg.	3/8"x4½" Kg.	Spikes Pcs.	13" Kg.	13" Pcs.	13" Cu.	Bolts Kg.	13" Pcs.	13" Cu.
									Rail, rubber joints				Spikes			Rail, new			Joints, new		
									Track												
14	1	4	300	610	120		10	25		2	195	5		8		112		12		15	1200	25			412	760
14	1	3						96								217										
16	2	9						20								64				10	1200	17				
17	2	10						80	60							448										
17	2	13				35	25	10		4	390	10		16		224										
18	2	13				30	35									224										
22	2	13						25								80										
18	1	4								8	780	20		32												
18	1	5																		15	1800	25				
Total			300	610	120	65	170	216		14	1365	35		56		1469				26	760	412				

Way Departments shown on page 278, Vol. 27 of the Proceedings of this Association. To date reports on the following forms have been presented:

Vol. 27 pp 277–278—Outline of typical reporting.
Vol. 26 pp 843–855—Foreman's Daily Time Report.
Vol. 27 pp 279–284—Labor Recapitulation and Distribution Sheet.
Vol. 30 pp 646–650—Track Foreman's Daily Material Report.
Vol. 31 pp 896–899—Foreman's Daily Report of Work Train Performance.
Vol. 31 pp 896–899—Conductor's Daily Report of Work Train Performance.
Vol. 34 pp 235–237—Foreman's Daily Report of Work Equipment.

This Committee this year submits a form to cover the Recapitulation and Distribution of Material.

Investigation by the Committee shows that some roads have forms with printed headings covering all items involved; others have forms partially printed, while others use forms with no printed headings.

The Committee believes that generally speaking a form with no printed headings is more flexible and economical. The form submitted by the Committee shows the title headings on the sheet printed but leaves all other spaces blank to be filled in.

In the exhibit as presented the form is partially filled out to show the manner in which it can be used.

Appendix G

(C–3) FORMS USED BY RAILWAY WATER SERVICE DEPARTMENTS, COLLABORATING WITH COMMITTEE XIII—WATER SERVICE AND SANITATION

D. C. Teal, Chairman, Sub-Committee; James Erskine, W. E. Gardner, F. C. Kane, J. R. Leguenec, Jr., F. X. Soete, James Stephenson and Louis Wolf.

Four forms dealing with water station records are shown in the 1929 Manual on pages 955 to 958, inclusive. Since the adoption of these forms in 1909, many changes have been made in the organization of Railway Water Service Departments and in the methods of pumping and treating water.

The work of the Committee has been to develop an up-to-date system of Water Supply Department forms to replace the obsolete ones now appearing in the Manual.

In the pursuance of the assignment, forms now in common use by Railway Water Service Departments have been collected and classified. Forms representing each general classification have been designed and presented to the Association during the past three years as follows:

	Proceedings Reference			
Name of Form	*Vol.*	*Year*	*Page*	*Form Number*
Cost of water production	32	1931	524	1302–Rev.
Monthly report of water station operation	33	1932	599	1301–Rev.
Quarter monthly report of water treating plant operation	34	1933	240	1301–A
Record of water station facilities	34	1933	241	1303–Rev.

Form 1302–Rev., 1301–Rev., and 1303–Rev., are up to date versions of forms now appearing in the Manual. Form 1301–A is a form necessitated by the development of present-day water treatment practices and has no counterpart at present in the Manual.

It is believed that the above forms together constitute an up-to-date system of essential water supply department forms that fulfill the requirements and cover the needs of present-day water service organizations.

Action Recommended

In order to properly close the assignment, the Committee makes the following recommendations:

Cost of Water Production

It is recommended that Form 1302–Rev., together with text relative to same, as presented on pages 523 and 524 in Vol. 32 of the 1931 Proceedings, be published in the "Records and Accounts" section of the Manual. It is further recommended that the designation "Form 1302–Rev." be changed to read "Form 1130".

It is recommended that Form 1302 appearing on page 956 of the 1929 Manual be withdrawn.

Monthly Report of Water Station Operation

It is recommended that Form 1301–Rev. together with text relative to same, as presented on pages 599 and 600 in Vol. 33 of the 1932 Proceedings, be published in the "Records and Accounts" section of the Manual. It is further recommended that the designation "Form 1301–Rev." be changed to read "Form 1131".

It is recommended that Form 1301 appearing on page 955 of the 1929 Manual be withdrawn.

Quarter Monthly Report of Water Treating Plant Operation

It is recommended that Form 1301–A, together with text relative to same, as presented on pages 239 and 240 in Vol. 34 of the 1933 Proceedings, be published in the "Records and Accounts" section of the Manual. It is further recommended that the designation "Form 1301–A" be changed to read "Form 1132".

Record of Water Station Facilities

It is recommended that Form 1303–Rev., together with text relative to same, as presented on pages 241 and 242 in Vol. 34 of the 1933 Proceedings, be published in the "Records and Accounts" section of the Manual. It is further recommended that the designation "Form 1303–Rev." be changed to read "Form 1133."

It is recommended that Form 1303 appearing on page 957 of the 1929 Manual be withdrawn.

General

It is recommended that suitable reference notes to above forms be published in the "Water Service" section of the Manual.

Appendix H

(E–1) METHODS AND FORMS FOR GATHERING THE DATA FOR KEEPING UP TO DATE THE VALUATION AND OTHER RECORDS OF THE PROPERTY OF RAILWAYS WITH RESPECT TO:

(a) Changes made necessary by government regulations.

(b) Simplicity and practicability of use.

P. R. Leete, Chairman, Sub-Committee; B. A. Bertenshaw, E. Y. Allen, E. V. Braden, V. H. Doyle, W. E. Gardner, A. T. Hopkins, W. W. James, W. R. Kettenring, C. A. Knowles, E. W. Metcalf, A. T. Powell, H. L. Restall, James Stephenson, H. J. Stroebel, Louis Wolf, W. H. Woodbury.

The Emergency Transportation Act of 1933 has affected the valuation procedure through the amendment of Paragraphs (f) and (g) of Section 19a (Valuation Act) of the Interstate Commerce Act. The change can best be shown by the following comparison:

Section 19a as amended February 28, 1920, and June 7, 1922

"(f) Upon the completion of the valuation herein provided for, the Commission shall thereafter in like manner keep itself informed of all extensions and improvements or other changes in the condition and value of the property of all common carriers, and shall ascertain the value thereof, and shall from time to time, revise and correct its valuations, showing such revision and correction classified and as a whole and separately in each of the several States and Territories and the District of Columbia, which valuation, both original and corrected, shall be tentative valuations and shall be reported to Congress at the beginning of each regular session."

Section 19a as amended June 16, 1933

"(f) Upon completion of the original valuations herein provided for, the Commission shall thereafter keep itself informed of all new construction, extensions, improvements, retirements, or other changes in the condition, quantity, use and classification of the property of all common carriers as to which original valuations have been made, and of the cost of all additions and betterments thereto and of all changes in the investment therein, and may keep itself informed of current changes in costs and values of railroad properties, in order that it may have available at all times the information deemed by it to be necessary to enable it to revise and correct its previous inventories, classifications, and values of the properties; and when deemed necessary, may revise, correct, and supplement any of its inventories and valuations."

Section 19a as amended February 28, 1920, and June 7, 1922 (Cont'd)

"(g) To enable the Commission to make such changes and corrections in its valuations of each class of property, every common carrier subject to the provisions of this Act shall make such reports and furnish such information as the Commission may require."

Section 19a as amended June 16, 1933 (Cont'd)

"(g) To enable the Commission to carry out the provisions of the preceding paragraph, every common carrier subject to the provisions of this Act shall make such reports and furnish such information as the Commission may require."

The foregoing amendment and consequent reduction in appropriation has resulted in radical changes in the force and organization of the Bureau of Valuation, Interstate Commerce Commission, and the Director and Supervisors of this organization are making earnest efforts to reduce the expenditures for valuation both by the Commission and by the carriers. On account of the revision in the Transportation Act above quoted, there is a tendency to minimize the future importance of the property records which

have been inaugurated under the activities of Valuation Order No. 3. Under the revised section, the Commission is required to "keep itself informed of new construction, extensions, improvements, retirements, or other changes in the condition, quantity, use, etcetera," and at the present time, with the exception of those roads which *were* subject to recapture, the current requirements of Valuation Order No. 3 have not been materially reduced.

The Depreciation Order, the tentative revised classification, and Valuation Order No. 3 are so closely tied into each other that activities with respect to one should be closely coordinated with the activities of the others if economical handling is obtained. Ordinary accounting for property changes will not preserve the integrity of the engineering property inventories which have been made at great expense, and these records, so essential to accounting involving depreciation, should be maintained as an ordinary requirement to record the physical property of a railway company.

They have already been proven of great value in determining retirement information, in the many studies of consolidations and coordination of property; and will be a first requisite of Depreciation accounting. While the expense of initial preparation is great, many roads have found the current maintenance to be nominal and this Committee believes the railways will be amply compensated for their continued maintenance.

Appendix I

(E–2) METHODS USED IN RECAPTURE PROCEEDINGS

Chas. Silliman, Chairman, Sub-Committee; A. Anderson, H. T. Bradley, E. S. Butler, C. A. Knowles, J. R. Leguenec, Jr., W. S. McFetridge, E. W. Metcalf, James Stephenson, W. H. Woodbury.

Since the completion of the Committee's report appearing on page 246 of Vol. 34 of the Proceedings, Congress has made important changes in the Transportation Act.

By its Act of June 16, 1933 the Recapture Clause, Section 15a of the Interstate Commerce Act, was repealed and payments made thereunder ordered returned to the carriers.

The various recapture hearings that were set were pushed along until in May, when the passage of the repeal act being so imminent, they were suspended.

Conclusion

Your Committee desires to report the conclusion of the subject assigned and recommends its discontinuance.

Appendix J

(F–2) DEVELOPMENTS UNDER I.C.C. ORDER NO. 15100—DEPRECIATION CHARGES OF STEAM RAILWAY COMPANIES

J. H. Hande, Chairman, Sub-Committee; E. Y. Allen, B. A. Bertenshaw, A. M. Blanchard, E. V. Braden, H. T. Bradley, R. R. L. Bullard, V. H. Doyle, James Erskine, W. W. James, W. R. Kettenring, P. R. Leete, Henry Lehn, A. T. Powell, H. L. Restall, F. C. Sharood, H. J. Stroebel, G. R. Walsh, Louis Wolf.

The situation with respect to depreciation accounting remains unchanged from that reported at the last convention of this Association. The tentative draft of the new classification of accounts embodying depreciation accounting has not been made final and effective. This Committee is continuing its development of recommended procedure

under the provisions of the tentative draft of the classifications, and proposes to bring that recommended procedure into line with the final text of the classification as soon as it is published. That work is proceeding and, it is hoped, will produce results of value to the Association, if and when the regulations are made effective.

Appendix K

(F–3) METHODS FOR AVOIDING DUPLICATION OF EFFORT AND FOR SIMPLIFYING AND COORDINATING WORK UNDER THE REQUIREMENTS OF THE INTERSTATE COMMERCE COMMISSION

F. C. Sharood, Chairman, Sub-Committee; H. T. Bradley, V. H. Doyle, C. C. Haire, F. C. Kane, C. A. Knowles, W. M. Ludolph, Chas. Silliman, D. W. Smith, H. J. Stroebel.

The situation with respect to the rendition of a final report on this subject remains practically the same as that reported at the convention of this Association in 1933. Efforts have been made with the hope of securing recognition of this Association as a carrier agency.

Under date of March 7, 1933, the Chairman of Committee XI addressed a letter to the Board of Direction of the Association in which he placed the problem of securing the cooperation of other carrier agencies in the work being undertaken by this Sub-Committee frankly before the Board and asked assistance.

The Board of Direction discussed this letter at a meeting on March 13, 1933, and directed the President of this Association to discuss the matter with the President of the American Railway Association.

Shortly after April 1, 1933, the President of this Association had a conference with the President of the American Railway Association, who requested that the recommendation of this Association be definitely placed before him in writing.

This was done and recommendations made somewhat as follows: The President of the American Railway Association to call a conference of representatives of the American Railway Association, Engineering Division (A.R.E.A.), the Railway Accounting Officers' Association, and the Presidents' Conference Committee. There were to be five representatives from each of the foregoing organizations appointed to attend this meeting and through discussion to ascertain if anything could be accomplished by the formation of a joint committee, and make such recommendations as might be appropriate.

It is expected that this joint committee will be organized and sponsored by the A.R.A. at the opportune time.

Attention is called to an important development during the year when the "Emergency Transportation Act, 1933," approved June 16, 1933, in Title II, amended certain sections of the "Interstate Commerce Act." By Section 205 of the Emergency Transportation Act, 1933, Section 15a of the Interstate Commerce Act is amended so as to remove from Paragraph 2 of Section 15a, the requirement that rates shall be fixed to enable carriers to earn a "fair return upon the aggregate value of the railway property of such carriers held for and used in the service of transportation," and by striking out, in their entirety, Paragraphs 3 to 18, inclusive (Recapture Clauses). Section 206 of the "Emergency Transportation Act, 1933," provides for the termination of all proceedings in connection with recapture and the return of all moneys which had been paid by carriers as the result of such proceedings. Section 208 of the "Emergency Transportation

Act, 1933," amends Paragraphs (f) and (g) of Section 19a (Valuation Act) of the "Interstate Commerce Act." This change is specifically commented upon in the report under Appendix H relating to keeping up-to-date the valuation.

Another important development took place at the convention of the Railway Accounting Officers' Association in Chicago on last August 30th and 31st. Director Lewis of the Bureau of Valuation of the Commission talked informally to the General Accounts' Committee of that organization. During the course of his remarks, Director Lewis appealed for suggestions with respect to the modification and simplification of Valuation Order No. 3.

Since the above took place the Committee on Valuation Accounting from the Accounting Officers' Association is understood to have been given the duty of advising the Bureau of Valuation of the carriers' attitude and are now actively engaged in conferences with the accounting and engineering sections, with the thought of securing reductions in valuation requirements. It is significant that, while the Bureau is using joint engineering and accounting minds in these discussions, yet the carriers are not. It is hoped that the A.R.E.A. will be recognized and be permitted to take part in forming rules and regulations covering future accounting practices.

REPORT OF COMMITTEE XIII—WATER SERVICE AND SANITATION

R. C. Bardwell, *Chairman;*
W. R. Anthony,
W. M. Barr,
R. W. Chorley,
R. E. Coughlan,
W. L. Curtiss,
J. H. Davidson,
B. W. DeGeer,
A. F. Dorley,
R. N. Foster,
C. H. Fox,
J. H. Gibboney,*
W. P. Hale,
J. P. Hanley,
R. L. Holmes,
A. W. Johnson,
H. F. King,
C. R. Knowles,
J. J. Laudig,
M. E. McDonnell,
H. L. McMullin,
W. B. Nissly,
A. B. Pierce,
O. T. Rees,
C. P. Richardson,
J. A. Russell,
E. M. Grime, *Vice-Chairman;*
H. E. Sillcox,
D. A. Steel,
R. M. Stimmel,
C. P. Van Gundy,
H. W. Van Hovenberg,
R. E. Wachter,
J. B. Wesley,
A. E. Willahan,
R. S. Wilson,
J. B. Young,

Committee.

* Died October 30, 1933.

To the American Railway Engineering Association:

Your Committee on Water Service and Sanitation respectfully presents below its report to the Thirty-fifth Annual Convention on the following subjects:

(2) Cause and Extent of Pitting and Corrosion of Locomotive Boiler Tubes and Sheets (Appendix A).

(3) Methods and Value of Water Treatment, Summarizing Possible Savings Effected (Appendix B).

(4) Developments in Pipe Joints (Appendix C).

(5) Essentials of Mosquito Control (Appendix D).

(9) Disinfectants, Fumigants, and Cleaning Materials (Appendix E).

It is the recommendation of your Committee that the above reports be accepted as information.

Progress is reported on the following subjects:

(1) Revision of Manual.

(6) Design and Maintenance of Track Pans for Locomotive Water Supply.

(7) Methods for Analysis of Chemicals Used in Water Treatment.

(8) Progress being made by Federal or State Authorities on Regulations Pertaining to Railway Sanitation.

Respectfully submitted,

The Committee on Water Service and Sanitation,

R. C. Bardwell, *Chairman.*

James Haller Gibboney

It is with profound regret that your Chairman announces the death of J. H. Gibboney, Chief Chemist, Norfolk & Western Railway, on October 30, 1933.

Mr. Gibboney has been a tower of strength to the Water Service and Sanitation Committee, and his passing leaves a vacancy that will be difficult to fill.

Mr. Gibboney was appointed a member of the Water Service Committee in 1931, serving thereon until his death.

He was President of the American Society for Testing Materials in 1926–27, and Chairman of the Committee on Arrangements of this Association in 1933.

Mr. Gibboney was born at Wytheville, Virginia, on January 26, 1879, and was admitted to membership in the American Railway Engineering Association in 1911.

He was loyal to obligations and responsibilities assumed in the work of the several scientific and professional organizations to which he belonged, and in all of which he became an effective force and leader. His habit of mind, his industry, his sound judgment, and his practical conclusions on all topics submitted to his analysis made him an invaluable addition to the working force of any organization.

Those members who served with Mr. Gibboney will remember always the calm judgment and clear, intellectual analysis he brought to bear upon the many important questions which frequently arose in the Committee and to what extent his opinion and counsel were awaited.

Mr. Gibboney was by nature kindly and genial, inspiring the respect of all with whom he came in contact, and courteous in his bearing always. While he stood upon an eminence professionally reached by but a select few, he will be missed not alone by those of equal or similar attainments, but more especially by those among the lower ranks of the profession, to whom he was ever ready to extend a willing hand, and give wise counsel and assistance in reaching a higher plane of usefulness, and this was true as well in his relation to those with whom he worked and walked in his daily life, outside the sphere of the professional activities.

Appendix A

(2) CAUSE AND EXTENT OF PITTING AND CORROSION OF LOCOMOTIVE BOILER TUBES AND SHEETS

J. H. Davidson, Chairman, Sub-Committee; W. M. Barr, R. E. Coughlan, B. W. DeGeer, J. H. Gibboney, E. M. Grime, J. J. Laudig, M. E. McDonnell, H. L. McMullin, O. T. Rees, R. M. Stimmel, C. P. Van Gundy, R. S. Wilson, J. B. Young.

There have been no important developments in the theoretical aspects of this subject since the last report of this Committee. The basic and fundamental principles involved have been fully discussed in earlier reports appearing in Vol. 23, 25 and 26 of the Proceedings.

As a result of these studies, and experimental work, several proposed methods for inhibiting corrosion have been developed and most of them have been applied in actual service tests over a period of five to ten years.

These proposed remedies have been fully discussed in previous reports and as there have been no new methods of apparent outstanding merit introduced since the last report, the Committee has made an effort this year to collect information from representative railroads as to the present status of pitting and to ascertain what methods have proven most successful in actual service.

From the very start of the work on this subject, it seemed evident that the most available and logical method of attack was to properly condition the boiler water. It was found that by maintaining a sufficient degree of caustic alkalinity in the boiler water, most of the pitting and corrosion could be stopped. Accordingly the Committee developed a formula which serves as a guide. The experimental work by which this formula was developed is explained fully on page 378, Vol. 26 of the Proceedings.

Briefly stated, this formula provides for a caustic alkalinity in the boiler water equal to from 10 to 15 per cent of the total dissolved sodium sulphate and sodium chloride contained in the water.

Information collected this year shows that this is at the present time the outstanding method for inhibiting pitting and corrosion and that practically every railroad that has used this method under competent supervision has succeeded in greatly reducing the damage sustained on account of pitting and corrosion. The fact that this method also eliminates scale formation on heating surfaces adds to its popularity.

The use of corrosion resistant alloys in the manufacture of boiler tubes, flues and sheets has also been given considerable attention and many service tests have been conducted with these materials. Reports from various railroads indicate that to date these alloys have not generally proven economical. New alloys are being developed, and these should be given careful consideration as it is entirely possible that an alloy possessing the necessary qualifications will be eventually produced.

The counter electric potential method of preventing pitting and corrosion has proven beneficial in some cases, especially if the character of the water is such that removal of scale forming elements is not required. Since this method does not provide for removal of incrusting matter in the water it is in most cases advisable to use chemical treatment for this purpose and therefore more economical to properly regulate the treatment to also take care of the pitting.

The use of open feedwater heaters, protective coatings and many other proposed remedies for pitting have been tried with varying degrees of success, but none have thus far proven as dependable and economical as proper conditioning of the boiler feedwater.

Often two or more of the proposed methods can be combined with beneficial results.

One important fact deduced from information collected by the Committee is that it is very important to properly protect boilers of stored locomotives from being damaged

by pitting and corrosion. Boilers stored in good condition have been found to have practically the entire set of tubes rendered useless by corrosion after storage period of from two to four years.

This is an important matter when so many locomotives are stored in good order as has been the case in recent years.

Climatic conditions play an important role in this sort of corrosion, it being extremely troublesome in localities near the seashore or where humidity is usually great. Flue mileage records of locomotives that have been stored several months instead of being worked continuously between flue renewals almost invariably make fewer miles between resetting of flues than those that have not had their service time interrupted by periods of storage.

While the care of boilers of stored locomotives does not usually come under the supervision of water supply engineers, yet it behooves those charged with the responsibility of providing suitable water for boilers to see that all concerned are informed regarding the possibility of damage to boilers of stored locomotives, to the end that the quality of the water will not be unjustly charged with the trouble which develops on account of pitting and corrosion in such boilers after resuming active service.

On page 270, Vol. 33 of the Proceedings, this Committee has described methods recommended for protection of boilers of stored locomotives. These methods, with variations to meet local conditions, are being used by many railroads at the present time. Experiments are being made with other methods. Your Committee feels that economies that may be effected by properly protecting the boilers of stored locomotives warrant more serious consideration by all concerned than is being generally given at present.

Appendix B

(3) METHODS AND VALUE OF WATER TREATMENT WITH RESPECT TO ESTIMATING AND SUMMARIZING POSSIBLE SAVINGS EFFECTED

R. E. Coughlan, Chairman, Sub-Committee; W. M. Barr, R. W. Chorley, J. H. Davidson, B. W. DeGeer, R. N. Foster, J. P. Hanley, J. H. Gibboney, R. L. Holmes, C. P. Richardson, R. M. Stimmel, H. W. Van Hovenberg, J. B. Wesley.

During the past year, your Committee has endeavored to summarize the monetary value of the various methods of water treatment with especial reference to the results obtained by the various railroads in the conservation of material, which was formerly destroyed by the use of unsuitable water; also to investigate the increased life of the locomotives as well as the additional work performed by such boilers, with the present reduced forces and shop expense.

While it has been a physical impossibility to obtain records of definite value from all of the larger railroads, sufficient information has been obtained to show the decidedly gratifying results now being obtained as a result of the installation of the various methods of correcting unsuitable water. A typical case of this nature on one of the larger Western railroads shows:

Five-year period

Application of new fireboxes	Reduction	89 per cent
" " new side sheets	"	91 per cent
" " new back flue sheets	"	84 per cent
" " new front flue sheets	"	96 per cent
" " new two-inch flues	"	83 per cent
" " new superheater flues	"	84 per cent

Storage of serviceable power has undoubtedly deferred considerable heavy repairs on all of the railroads, but in order to ascertain if possible the savings that could be attributed to water treatment, a study was made of the comparison of the reductions made necessary because of business conditions, between the mechanical repairs and the boiler repairs. It was found that the boiler repairs during this time showed a reduction of 24 per cent greater than the reduction in mechanical repairs as compared to normal operating conditions. Undoubtedly improved water conditions were responsible for this reduction.

Information now available shows that practically all of the large railroads equipped with water softening facilities are now operating boilers from 15 to 30 days between boiler washings as compared to the seven-day washout period of a few years ago. The locomotives are all actually operating a greater mileage daily so that the total mileage between boiler washings, combined with the longer runs, shows an increase of over 300 per cent as compared to former practice.

Possibly the most gratifying results shown on all of the larger railroads during the past year have been in the increasing number of extensions granted by the Federal Bureau of Steam Locomotive Inspection on locomotives that have operated the four-year period and which locomotives because of the excellent condition of the flues and boiler sheets are in condition to operate an additional year. These extensions are only granted after actual inspection by the Federal inspectors when in their opinion the claims of the railroads are justified. Without suitable water being supplied to the boilers these extensions would be impossible and the actual savings to the railroads because of these extensions return the cost of the investment in water softening facilities in a short time. On some of the railroads additional extensions have been granted after five years' operation which results in further savings formerly entirely out of the question because of the condition of the boilers prior to installation of water softening facilities.

Because of the general unsettled condition prevailing throughout the country which has affected railroad construction in particular, very few additional water treating facilities have been added to the railroads during the past year and while the programs of the various railroads for water softening have been temporarily deferred, the facilities now in service have proven to be one of the main factors in enabling the railroads to operate under decidedly adverse circumstances, so that with the resumption of normal operating conditions and more favorable income additional facilities will show decidedly favorable returns in districts which as yet have not been equipped to supply suitable water.

Appendix C

(4) DEVELOPMENTS IN PIPE JOINTS

R. L. Holmes, Chairman, Sub-Committee; B. W. DeGeer, C. H. Fox, E. M. Grime, J. P. Hanley, A. W. Johnson, W. B. Nissly, A. B. Pierce, A. E. Willahan, H. E. Sillcox.

History

The transportation of water dates back to about 3000 years B.C. The only materials available which could be used for this purpose were wood, stone, lead and pottery; and doubtless the engineers of that time adopted the most economical method of crossing depressions, which was the conduit or aqueduct supported on arches.

The Romans and Greeks well understood the principle of the inverted siphon, one of which was constructed in the works at Lyons, France, which consisted of nine miles of lead pipe, varying in diameter from twelve to eighteen inches and working under a head of two hundred feet.

The lead pipe was produced by working the material into sheets and bent round a core, forming a lap joint and soldered. One end of each section of pipe was expanded sufficiently to form a telescopic joint and on laying the end lap was soldered.

Many of the chief cities of the Roman Empire were served by aqueducts, some of which were forty miles in length, including several thousand feet of tunneling. Rome was at one time supplied from fourteen different aqueducts, the first of which was constructed about 312 B.C.

The distribution of water in this age was by no means general. From the aqueducts the water was passed into large reservoirs or cisterns, thence through lead, stone or clay pipe to smaller cisterns, and to fountains, baths and public buildings. The general public obtained their supply from the fountains.

The development of modern waterworks began in Europe and British Isles during the latter part of the Sixteenth Century A.D., but little progress was made until 1761, during which time pipe of stone, wood, cast lead and pottery was used in laying water mains.

Quoting Professors Turneaure and Russell—

"For many years the larger pipes were usually of wood, made by boring out logs to a diameter of six or seven inches. Cast iron pipes came into general use about 1800; and in 1820 the New River Company of London replaced its wooden mains with cast iron ones at a cost of $1,500,000. At one time this company had about 400 miles of wooden pipe in use, and often as many as ten lines of pipe were laid side by side to form a single main."

The first cast iron pipe of which we have record was made at Versailles in 1664, but due to its cost, its use was very limited until 1738. This pipe was made in relatively short lengths (approximately 39 inches) the ends of which were flanged, octagon in shape, and bolted, using a lead gasket. Some trouble was experienced through the rusting of bolts, which permitted the joints to leak.

The first general waterworks system to be constructed in America was at Boston in 1652. Following the practice of Europe, bored logs were used until about 1817 when a small quantity of cast iron pipe, bell and spigot joint was imported from England, replacing some wood pipe then in service at Philadelphia.

Throughout the ages the weak link has been the joint, the result of which no doubt is responsible for the varied designs.

Joints and Their Development

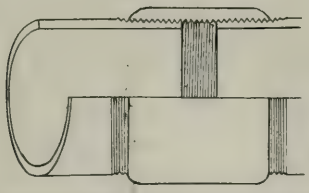
The mortised and tenon joint predominated in ancient lines of stone, pottery, and wood, while telescopic, soldered applied to the rolled lead and flanged joints applied to cast lead.

Screw Joints for Wrought, Steel and Cast Iron Pipe

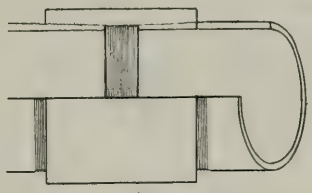
Wrought iron tubes were first made into gun barrels. The metal was hand hammered into sheets, then formed into cylinders and lapwelded over a mandrel. This practice began in the thirteenth century and continued to about 1824, when James Russell patented the buttweld process which was improved by Cornelius Whitehouse in 1825, by using the bell or die through which the plate or skelp was drawn to form the cylinder.

Steel tubing, both butt and lapwelded longitudinal joints, was first manufactured in 1887, or about 17 years after the invention of the Bessemer converter.

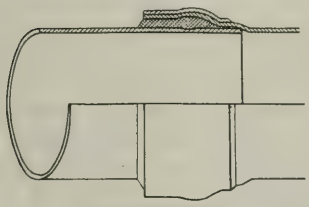
Joining together the tubes to create a pipe line was first accomplished by William Murdock at London in 1815 when he screwed together a quantity of old musket barrels to convey coal gas from the generators to various points for burning. From this time



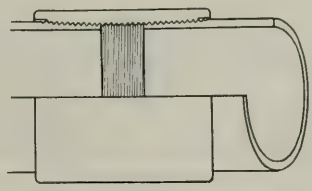
BRIGGS OR AMERICAN STD PIPE COUPLING AND JOINT
FIGURE 1



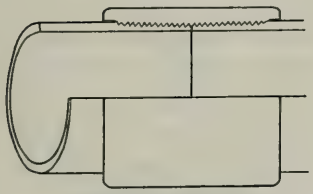
ENGLISH STEAM AND GAS TUBE
FIGURE 2



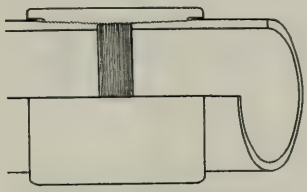
MATHESON JOINT
FIGURE 3



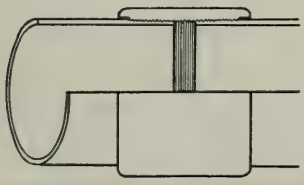
LINE PIPE COUPLING AND JOINT
FIGURE 4



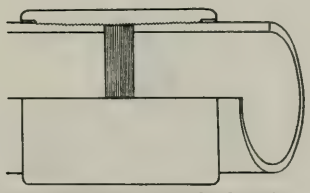
DRIVE PIPE COUPLING AND JOINT
FIGURE 5



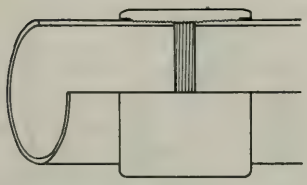
OIL WELL TUBING COUPLING AND JOINT
FIGURE 6



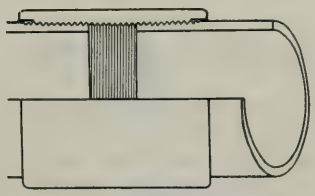
BOSTON MERCHANT CASING COUPLING AND JOINT
FIGURE 7



SOUTH PENN CASING COUPLING AND JOINT
FIGURE 8

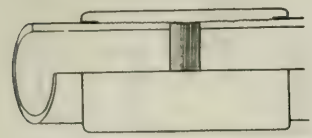


BOSTON OIL WELL CASING COUPLING AND JOINT
FIGURE 9

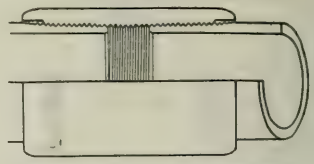


REAMED AND DRIFTED PIPE COUPLING AND JOINT
FIGURE 10

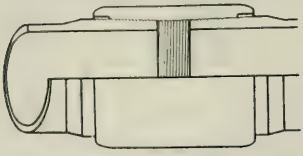
Plate A



DIAMOND BX CASING COUPLING AND JOINT
FIGURE 11

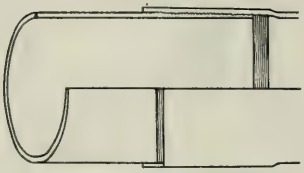


ROTARY DRILL PIPE COUPLING AND JOINT
FIGURE 12

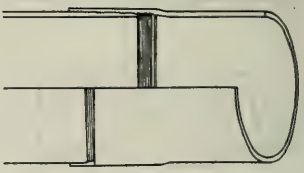


EXTERNAL UPSET TUBING COUPLING AND JOINT
FIGURE 13

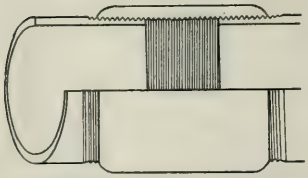
INTERIOR UPSET DRILL PIPE COUPLING AND JOINT
FIGURE 14



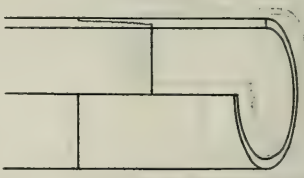
EXPORT STANDARD INSERTED JOINT CASING
FIGURE 15



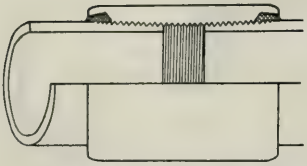
BOSTON INSERTED JOINT CASING
FIGURE 16



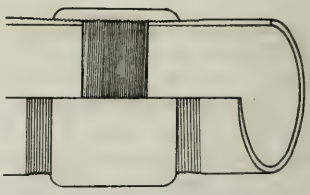
AMMONIA PIPE COUPLING AND JOINT
FIGURE 17



FLUSH JOINT TUBING
FIGURE 18



AIR LINE PIPE COUPLING AND JOINT
FIGURE 19



DRY KILN PIPE COUPLING AND JOINT
FIGURE 20

Plate A–1

to 1862 each manufacturer of tubing had his individual specifications covering thickness of wall, diameter of pipe and thread size, when Robert Briggs formulated the dimensions of pipe threads, and compiled a table giving the normal size, the exact diameters and number of threads per inch for all sizes of pipe up to 10 inches. These formulas and tables were subsequently adopted as standard for the manufacture of all tubes and pipes up to 15 inches in diameter and are now known as "American Standard"—Plate A, Fig. 1. There are numerous other screw joints in use, sketches of which are shown on Plate A and A1, Fig. 2 to 20, which have a special service, such as is required in the oil or gas industry, well drilling, casing, etc., although these joints may be used in water lines.

Cast Iron Screw Joints

Cast iron screw joints, American standard thread, are now available in 6-ft. lengths, varying in diameter from 1½ to 6 inches inclusive.

Screw Flanged Joints for Wrought or Steel Pipe

The screw flanged joint is usually used in lines of greater diameter than three inches. The principal advantage in this type of connection is the ease and readiness with which sections of the line may be removed or replaced. For excessive pressures, it has been found advisable to weld the flange to the pipe after screwing on, thus becoming a part of the pipe itself. Another very popular flanged joint is the Van Stone, created by slipping flange over the smooth end of pipe, which is then heated, upset and flared hot, at right angles to the pipe itself. To insure a tight joint the flared ends of the pipe are faced, so that when the pipe is in position the ends will fit snug against the gasket—Plate C, Fig 26.

Riveted Joints for Wrought or Steel Pipe

Normally used is the butted-and-strapped and bump joint. The first is made by butting the two pipe ends together, covering the joint with a snug fit slip sleeve or strap externally or internally, the former preferred, and then rivet and calk. The bump joint is made by expanding one end of the pipe for a short distance to slip over the other, then rivet and calk. Riveted joints are not generally used in lines of less than 28 inches in diameter.

Welded Joints of Wrought and Steel Pipe

Welding of wrought and steel pipe joints began about 1910, but little progress was made until 1914 when trunk line construction began. During the past ten years hundreds of miles of eight to twenty-inch welded steel lines have been laid for conveying oil, gas and gasoline from the mid-continent fields to points North and East.

Until recently welding rods of so-called Norway iron were used, which has a tensile strength of 47,000 lb. per sq. in. for single vee welds and 52,000 lb. per sq. in. for double vee welds. Obtainable today are rods which have a tensile strength of 56,000 lb. per sq. in. for single vee welds and 60,000 lb. per sq. in. for double vee welds with consistent regularity by welders of average ability.

A larger portion of the trunk lines in service today are the acetylene welded, the cost of which is approximately 45 per cent of the screw joint type. The price of welding depends upon the fluctuation of labor and material cost, but for estimating purposes the following may be used, which covers cost of materials and labor in welding only, using standard weight pipe, butt welds, the pipe being previously beveled.

2	inch	to	6	inch	in	diameter	— 12¢	per	inch	diameter	per	joint
7	"	"	12	"	"	"	— 15¢	"	"	"	"	"
14	"	"	30	"	"	"	— 20¢	"	"	"	"	"

Electric welding is used, and it is reported that with the new process of electric welding, a tensile strength of 70,000 lb. per sq. in. is obtainable, with an elongation of 30 to 35 per cent in two inches. The Committee was unable to obtain definite figures as to cost of this type of welding.

Welded Cast Iron Pipe

The use of welded or brazed cast iron joints began about 1921, using the collar type joint made by depositing a bronze collar around the abutting ends of the pipe, using the acetylene process. This type of joint proved successful in so far as tightness was concerned but failures began to occur with the approach of the first winter following installation, due to the pipe breaking adjacent to weld.

The next experiment was by using the vee type bronze weld, but this joint developed only about 40 per cent of the pipe strength. Failure occurred along bevel line.

In 1924 the bevel-overlap joint was used with success. This type of joint develops the strength of the pipe up to 4 inches in diameter.

In 1926 the shear-vee bronze weld type of joint was developed, which is claimed to be 100 per cent efficient in sizes up to 8 inches in diameter.

Welding materials other than bronze have been used, but tobin bronze rods are so far found to be the best. Experimental work conducted on Pacific Coast in 1921 by Messrs. Bridge and Thompson indicated a 4-inch cast iron pipe was the largest with which cast iron welding rods could be used without preheating or annealing. Special care should be used in obtaining a true alinement prior to welding, and in backfilling and tamping the lower half of pipe to prevent beam action.

Expansion and contraction is an important factor in laying welded cast iron joints, but actual field test during 1927 indicated that the common formula for calculating expansion does not apply on buried lines. Two sections of line were used in the test, one having a length of 143 feet, the other 450 feet. In the former and with a maximum range of temperature of 120 degrees the measured elongation was 76 per cent of the calculated. In the latter case and a maximum range of 82 degrees the measured elongation was 24 per cent of the calculated.

The formula used in calculating follows—

$$\text{Elongation in feet} = \text{length} \times \text{range} \times \text{coefficient } (.000006)$$

Typical cross-sections of brazed or welded cast iron joints, and indicating points of failure are shown on Plate C—Fig. 22 to 25 inclusive.

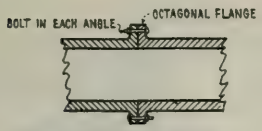
On plate B and B1 are shown 72 different kinds of cast iron joints—Fig. No. 1 showing the first joint of record.

Beginning with Fig. 35 to and including Fig 53—Plates B and B1 all of which may be used with steel or wrought pipe.

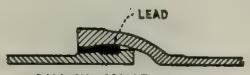
Bell and Spigot Joint Cast Iron Pipe

The first cast iron pipe of which we have record was made at Versailles in 1664 but cast iron was not generally used until 1738, when the bell and spigot joint was first introduced.

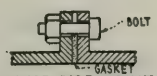
Many different joint materials and combinations of materials have been used in laying cast iron pipe, but lead seems to have been most generally used up to a few years ago. The least expensive and as reliable as any is standard Portland cement and dry jute or oakum.



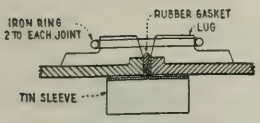
FLANGE JOINT-VERSAILLES-1664.
FIGURE 1.



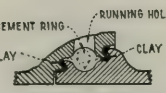
BALL AND SOCKET JOINT
FIGURE 2.



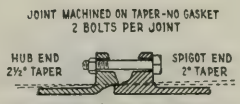
FLANGE PIPE JOINT
FIGURE 3.



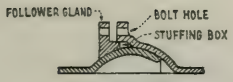
"CLARK PATENT" JOINT
FIGURE 4



YARROW JOINT
(PAT. BY MATTHEW YARROW OF BOLTON, ENG.)
FIGURE 5.



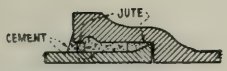
UNIVERSAL CAST IRON JOINT
FIGURE 6.



C.I. BALL & SOCKET PIPE JOINT
FIGURE 7.

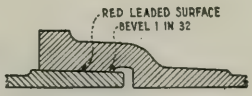
SIMPLEX PREPARED JOINT
FIGURE 8.

COMBINATION LEAD & JUTE JOINT-NO.1 BELL.
FIGURE 9.



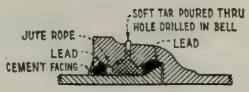
COMBINATION CEMENT & JUTE JOINT-NO.1 BELL.
FIGURE 10.

SALAMMONIAC RUST JOINT.
FIGURE 11.



TURNED AND BORED JOINT.
FIGURE 12.

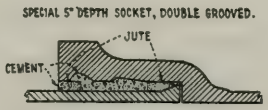
IMPROVED TURNED AND BORED JOINT.
FIGURE 13.



COMBINATION JOINT.
FIGURE 14.

BALL & SOCKET PREPARED JOINT.
FIGURE 15.

PREPARED JOINT
FIGURE 16.

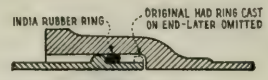


CEMENT & JUTE JOINT
FIGURE 17.

CEMENT JOINT-NO. 2 BELL
FIGURE 18.

Plate B

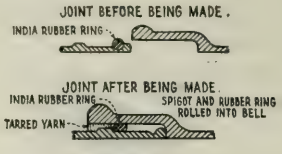
TAPER COLLAR FOR PLAIN END PIPE.
FIGURE 19.



ZIEGLER INDIA-RUBBER RING JOINT.
FIGURE 20.

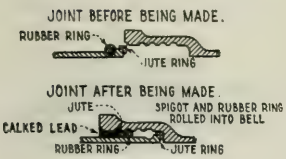
WILHELM JOINT
FIGURE 21.

WILHELM JOINT
FIGURE 22



FORSTER JOINT.
FIGURE 23.

SOMZEES JOINT (FRENCH)
FIGURE 24.



ZIMMERMAN JOINT.
FIGURE 25.

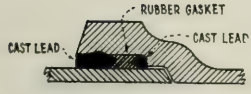
TRIFET JOINT (FRENCH)
FIGURE 26.

BIGLER RING JOINT
FIGURE 27

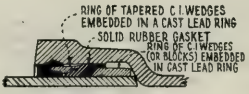
BIGLER JOINT
FIGURE 28.

SOUTHWESTERN JOINT
FIGURE 29.

B & S. PIPE WITH WEDGETITE RING.
FIGURE 30.

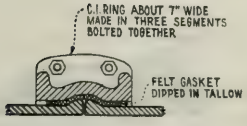


SOUTHWESTERN PRE-POURED JOINT.
FIGURE 31.



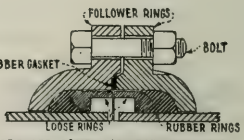
FLEXPAN JOINT.
FIGURE 32.

BOLTLESS SIMPLEX JOINT.
FIGURE 33



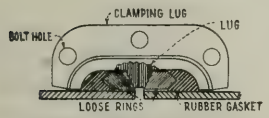
NEW RIVER CO. PIPE JOINT.
FIGURE 34

DRESSER COUPLING - PAT. MAY 1, 1888.
FIGURE 35.

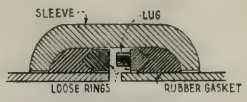


DRESSER COUPLING - PAT. MAY 1, 1888.
FIGURE 36.

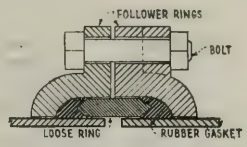
Plate B



DRESSER COUPLING - PAT. MAY 1, 1888.
FIGURE 37.

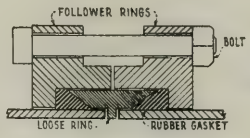


DRESSER COUPLING - PAT. MAY 1, 1888.
FIGURE 38

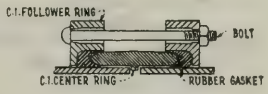


DRESSER COUPLING - PAT. SEPT. 18, 1888
FIGURE 39

DRESSER COUPLING - PAT. APRIL 2, 1889
FIGURE 40



DRESSER COUPLING - PAT. JULY 2, 1889.
FIGURE 41



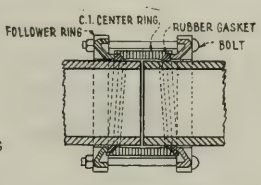
DRESSER COUPLING.
FIGURE 42

DRESSER COUPLING.
FIGURE 43.

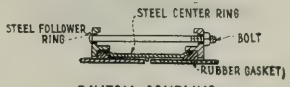
DRESSER COUPLING.
FIGURE 44

PANTE CULLEN JOINT.
FIGURE 45.

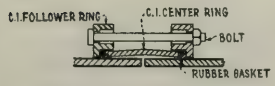
EUREKA JOINT (MALLEABLE)
FIGURE 46



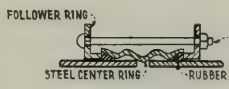
EARLY HAMMON COUPLING
FIGURE 47



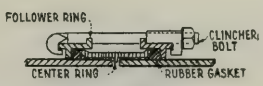
DAYTON COUPLING.
FIGURE 48.



GIBAULT PATENT COUPLING (FRENCH)
FIGURE 49

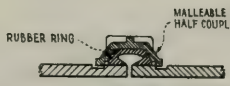


EARLY CUSTER COUPLING
FIGURE 50.

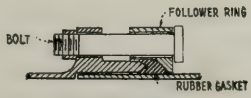


HAMMON CLINCHER
FIGURE 51

VICTAULIC COUPLING ON C.I.P WITH BEADED ENDS
FIGURE 52.

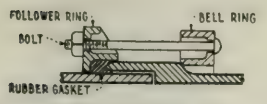


VICTAULIC COUPLING ON C.I.P. WITH GROOVED ENDS.
FIGURE 53.

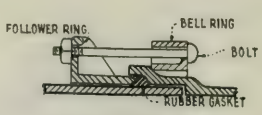


DRESSER COUPLING PIPE.
FIGURE 54

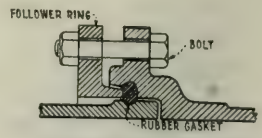
Plate B-1



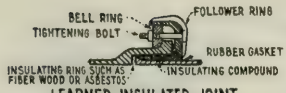
DRESSER COUPLING PIPE
FIGURE 55



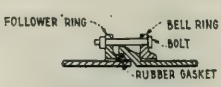
DRESSER COUPLING PIPE
FIGURE 56



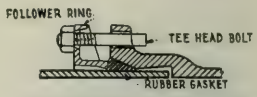
MACNAUGHTAN'S ACME JOINT
FIGURE 57



LEARNED INSULATED JOINT
FIGURE 58

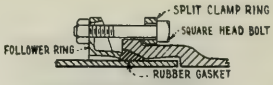


PATENT "TRUE" JOINT
FIGURE 59.

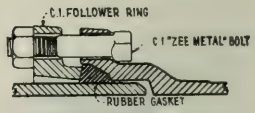


ANTHONY JOINT-INTEGRAL FLANGE TYPE
FIGURE 60

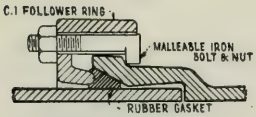
CLOWS EXPANSION JOINT PIPE
FIGURE 61



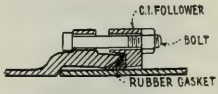
ANTHONY JOINT-CLAMP RING TYPE
FIGURE 62



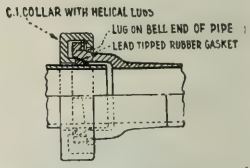
DOUBLEX SIMPLEX JOINT.
FIGURE 63



CARSON JOINT
FIGURE 64

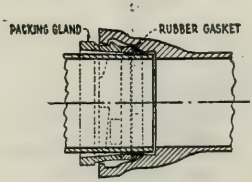


BOLTITE JOINT
FIGURE 65

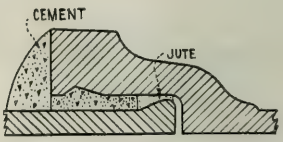


SELF-ADJUSTING STANTON-WILSON PIPE JOINT.
STANTON IRON WORKS-ENGLAND
FIGURE 66

GLAMORGAN JOINT
FIGURE 67



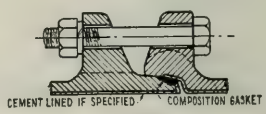
"LOCKCLAMP" OR "WEAVER" JOINT
FIGURE 68



A.W.W.A. NO. 1 & NO. 2 BELLS-JUTE AND CEMENT
FIGURE 69

DELAVAUD JOINT.
FIGURE 70.

BEVELED BELL-DUTCH TYPE-PLAIN SPIGOT.
FIGURE 71.



DUAL-LOK JOINT.
FIGURE 72

Plate B–1

The cement joint passed its experimental stage from 1913 to 1915 during which time varying combinations were tried, none proving as efficient, however, as the joint shown on Plate B1—Fig. 69 and 70. The cement and jute joint is suitable for use under most conditions applying to lead or joint compositions. The secret of the cement joint is in getting a good yarning job. The bell and spigot end should be thoroughly cleaned. The spigot well centered to give an equal distribution of jute and cement. In applying the customary rings of jute, the ends should lap and the jute compressed (by driving) to depth thickness of approximately ¾-in., then prepare and add the cement.

Many cement joint advocates recommend keeping pressure off of green joints for 24 to 48 hours. This delay is not necessary for there is not sufficient moisture added to the cement to complete hydration until the pressure is on the line and the water slowly percolates through the jute. Many joints in moderately low pressure lines have been examined after two years' service and found to contain two to three inches of unset cement. On lines of 100 to 180 lb. pressure all joints examined indicated complete set.

Three all-cement joint lines have been under observation for three years, one of which is seventeen miles in length composed of 10 and 12-inch pipe working under a maximum pressure of 165 lb. Another line 12 miles long composed of all 10-inch working under a maximum pressure of 170 lb. The third line five miles in length composed of 8 and 10-inch pipe working under a maximum pressure of 150 lb. These lines were recently tested for leakage, neither of which showed a loss of more than 1 GPM. The lines are in a semi-arid country where the atmospheric temperature varies 132 degrees.

When these lines were laid a saving of $22,000 was effected over the next cheapest jointing material considered.

Mechanical Cast Iron Pipe Joints

On Plates B and B1—Fig. 34 to 66 are shown about 32 different kinds of mechanical joints, some of which have been thoroughly tested. See 1932 report of Peoples Gas Light & Coke Company and the United Gas Improvement Company cooperating with the American Gas Association. Also see report No. 706 of American Gas Association Testing Laboratory as of February 22, 1933.

Cast Iron Bell Joint Clamps

Two means are used to repair leaking bell joints. First, to either recalk or remake the joint or, second, to apply leak clamps, which are shown on Plate C—Fig. 1 to 21.

Fire Hose Couplings

Through the efforts of the National Board of Fire Underwriters a National Standard has been adopted by a majority of the States covering fire hose couplings. Prior to about 1919, the fire fighting equipment, especially hose connections of one municipality were not interchangeable with another, the result was that in lending aid, much valuable time was lost in making adapters, before assistance could be given. Texas is reported to be the only state that is 100 per cent standardized.

Transite Pressure Pipe and Couplings

This product is a mixture of Portland cement and asbestos fiber and contains no other reinforcement. It has been manufactured in Italy for about fifteen years, and now obtainable in America. The length of joint is ten feet, for diameters of 2 to 7 inches inclusive, and in 13-feet lengths for diameters of 8 to 36 inches.

The weight per cubic foot is about 28 per cent of sand cast pipe and has five classifications, namely, A, B, C, D, and E, following the practice of the American Waterworks Association. The manufacturer recommends Simplex Coupling, Plate C—Fig. 29, but

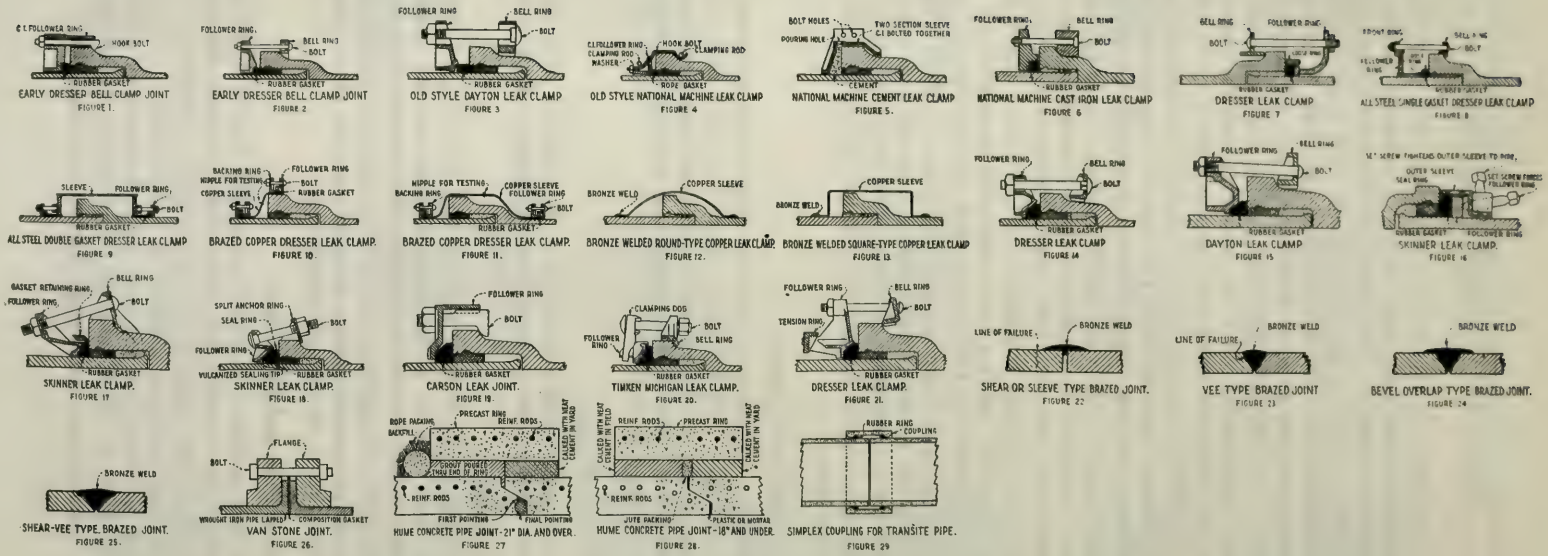

EARLY DRESSER BELL CLAMP JOINT
FIGURE 1.
EARLY DRESSER BELL CLAMP JOINT
FIGURE 2
OLD STYLE DAYTON LEAK CLAMP
FIGURE 3
OLD STYLE NATIONAL MACHINE LEAK CLAMP
FIGURE 4
NATIONAL MACHINE CEMENT LEAK CLAMP
FIGURE 5.
NATIONAL MACHINE CAST IRON LEAK CLAMP
FIGURE 6
DRESSER LEAK CLAMP
FIGURE 7
ALL STEEL SINGLE GASKET DRESSER LEAK CLAMP
FIGURE 8
ALL STEEL DOUBLE GASKET DRESSER LEAK CLAMP
FIGURE 9
BRAZED COPPER DRESSER LEAK CLAMP.
FIGURE 10.
BRAZED COPPER DRESSER LEAK CLAMP.
FIGURE 11.
BRONZE WELDED ROUND-TYPE COPPER LEAK CLAMP.
FIGURE 12.
BRONZE WELDED SQUARE-TYPE COPPER LEAK CLAMP
FIGURE 13.
DRESSER LEAK CLAMP
FIGURE 14
DAYTON LEAK CLAMP
FIGURE 15
SKINNER LEAK CLAMP.
FIGURE 16
SKINNER LEAK CLAMP.
FIGURE 17
SKINNER LEAK CLAMP.
FIGURE 18.
CARSON LEAK JOINT.
FIGURE 19.
TIMKEN MICHIGAN LEAK CLAMP.
FIGURE 20.
DRESSER LEAK CLAMP.
FIGURE 21.
SHEAR OR SLEEVE TYPE BRAZED JOINT.
FIGURE 22
VEE TYPE BRAZED JOINT
FIGURE 23
BEVEL OVERLAP TYPE BRAZED JOINT.
FIGURE 24
SHEAR-VEE TYPE BRAZED JOINT.
FIGURE 25.
VAN STONE JOINT.
FIGURE 26.
HUME CONCRETE PIPE JOINT-21" DIA. AND OVER.
FIGURE 27
HUME CONCRETE PIPE JOINT-18" AND UNDER.
FIGURE 28.
SIMPLEX COUPLING FOR TRANSITE PIPE.
FIGURE 29

Plate C

will furnish if the purchaser so desires, Dresser, Dayton or Flanged Couplings, and advises against the use of rubber ring where temperatures of over 175 deg. F., are encountered or in handling solvents of rubber in which event special gasket material will be furnished.

Reinforced Concrete Pressure Pipe

Until about ten years ago, reinforced concrete pipe was principally used in sanitary and storm sewer work, but since that time and with the centrifugal process a very dense pipe is produced that has a lower resistance to flow of water than steel or iron.

On Plate C—Fig. 27, are shown two types of joints for pipe diameters 21 inches and above and Fig. 28 for pipe 18 inches and below.

The manufacturers of centrifugal concrete pipe guarantee seepage losses to less than 200 gallons per inch diameter, per mile, per day of 24 hours. A number of tests have been made, none of which exceeded the allowable, and in many cases the loss was as low as eight per cent of the allowable.

This Committee desires to express to the American Gas Association, the American Petroleum Institute, Pipe and Joint Material Manufacturers our appreciation for information used in this report.

Appendix D

ESSENTIALS OF MOSQUITO CONTROL

By H. W. Van Hovenberg

A considerable portion of the population of the United States is not interested directly in the problem of mosquito control from the standpoint of protection from mosquitoes that carry disease, such as malaria fever, because of the geographical limits of the disease habitat, notwithstanding a better appreciation of the South's malaria problem would possibly be to the advantage of the Northern investor in many ways. The entire population does concern itself in the control of mosquitoes to eliminate the mosquito as a pest, so that in the past fifteen years we have seen many mosquito abatement districts formed which may be classed as major engineering operations, involving the spending of hundreds of thousands of dollars annually.

Control of the pest mosquito is obviously for human comfort, both in dwellings and in the open, and for the protection of laborers, both day and night. In some sections of the country live stock and poultry have to be given some measure of protection. The creation of some resort areas has been dependent on the control of the mosquito pest. Cities are now engaging engineers to direct mosquito control work in order that public parks, swimming pools, golf courses, and playgrounds may be made enjoyable.

Along the New Jersey coast, where there are hundreds of thousands of acres of marsh lands producing mosquitoes, abatement districts have not only controlled the pest at unbelievably low costs, but have enhanced property values to much more than pay for the engineering work involved. These results were obtained by the development of power ditching machinery, use of tide gates and pumping plants, and chiefly by an excellent understanding of the problem by the mosquito abatement officials.

A new interest in the control of disease carrying mosquitoes is in the studies that are being made to forestall the bringing into this country of new varieties of mosquitoes, or of infected mosquitoes, that are proven carriers of malaria or of yellow fever, by airplane or ship, or of the diseases by infected humans at the borders.

The control of mosquitoes that transmit disease may be instituted to prevent the possibility of a disease, such as yellow fever, from getting into the country. For ex-

ample, we have the mosquito Aedes aegypti breeding in abundance over most of the United States, and ready to spread yellow fever should a person infected with the disease enter the country and be bitten by these mosquitoes, and the disease via the mosquito carried to well persons. A control project may be planned to stamp out an incipient flareup of yellow fever, or malaria, or dengue, or may be planned to eradicate disease where it has been long established. The engineering methods for these different conditions of control will vary.

Changes in natural topography, such as the impounding of large or small bodies of water, have brought a change in the varieties of mosquitoes, and in the case of malaria fever, have been responsible in many instances for the rapid spreading of the disease, so much so that a number of states now have laws governing the conditioning of water power sites. A considerable amount of mosquito research work has been done in this country, chiefly by the United States Public Health Service, in order to arrive at methods that should apply to areas embraced in impounded water projects. Both minor and major drainage projects, particularly in the Southern states, have complicated the spread and the control of malaria fever.

Our railroads have their mosquito problems, both from the standpoint of pest and disease, direct and indirect. Railroad labor is affected by both pestiferous and disease-carrying mosquitoes. It is quite impossible for any laborer to return a decent output for his hire if he is kept awake at night by pest mosquitoes, and likewise utterly impossible for him to return even a feeble effort for his pay if he is suffering with malaria.

Indirectly the railroads operating in the malaria belt suffer from decreased production from farm and factory in those sections where the disease is rampant, both by decrease in freight haul from such places and to such places, for such communities neither produce nor have the surplus from their labor to purchase. The mutual interest of railroads and communities is intensified in those sections in which malaria is still a serious public health problem, and it is undoubtedly true that no other preventable disease affects railroad operation in the South as does malaria. How serious this problem is, is reflected in a study of railway hospitals in the South, which showed that fully one-third of all hospital medical cases were chargeable to malaria, not including the many seriously complicated surgical cases, or the larger number of employees getting relief from malaria through local surgeons or other agencies.

For any mosquito control problem, the solution requires a knowledge of the kinds, habits, flight range, seasonal breeding, and other characteristics of mosquitoes, and a thorough understanding of field engineering methods for their control, including ditching by hand, machine, and dynamite; oiling, dusting with Paris green; brushing and clearing of water courses; inner ditching and lining; use of mosquito larvae eating fish; screening; and prophylaxis. Since the World War this work of controlling mosquito production has given employment to many engineers and others, and the science of control has progressed to the point where it may be called a profession. Many of our engineering associations have sections, or scientific reports, devoted to the subject. Similar to any other engineering project, the control of mosquitoes involves planning, research, organization, and adequate direction.

With particular reference to railroads, the problem of protecting employees from malarial infection is complicated because of the various conditions under which certain groups of them live and work. Bridge and building, extra gang, and other mobile forces, spend much of their time in river bottoms where they are necessarily exposed to hordes of mosquitoes. These men, living in camp cars, usually average about six per cent of the total railroad employees, yet in the South have furnished railroad hospitals with about thirty-five per cent of the malaria cases. Shopmen, most of whom live in

larger communities, comprise about thirty per cent of the employees, and furnish about twelve per cent of the malaria cases. In normal times about twenty per cent of employees are section laborers, and they have usually supplied forty per cent of the hospital malaria cases. These figures have been cited to show the range of infection by groups, and because the method of control of malaria will differ with each group.

Any plan of control should be based on securing the maximum protection for the least cost, and every known method can be applied. For the protection of men employed in shop towns, it will generally be found most expedient to eradicate mosquitoes by drainage, oiling, filling, use of fish, and other field control means. For mobile units, such as Bridge and Building gangs, the first step should be the proper screening of their sleeping and eating quarters with sixteen-mesh wire screens. Locating outfit cars in localities free from malaria mosquitoes whenever possible, swatting mosquitoes in cars, and use of quinine as a possible prophylaxis, will also be effective. Isolation of patients under treatment for malaria, screening of houses, and use of quinine, will generally suffice for protection of employees living in section houses. The above three classes of employees comprise approximately fifty per cent of the total employees of a railroad in normal times, and in the South will furnish better than eighty-five per cent of the railroad hospital cases.

The economy of malaria control in behalf of railroad employees in the South has been amply demonstrated by the pioneer work of the St. Louis Southwestern Railway, beginning in 1917, and by the subsequent adoption of similar work on the Missouri Pacific and the Rock Island railroads. The net result of the railroad malaria and mosquito work has been its spread to practically all cities and towns in the South.

Probably the most outstanding single piece of health legislation in the South is that of the creation of the Texas Malaria Unit designed to bring the story of malaria, and its cause and prevention, to the inhabitants of seventy-two counties, having an area greater than the six New England states. This project was fostered by the East Texas Chamber of Commerce as a purely economic venture, and a state legislative appropriation of $50,000 made to cover the work for two years, coming to a close September 1st, 1933. The most outstanding achievement in connection with this project was the enlisting of the educational forces of the state, the Parent Teachers' Associations, the Women's Clubs, and of most particular importance, of the Home Demonstration Clubs of farm women, in the study of malaria in schools and in the application of anti-malaria measures about rural homes.

The interest of our railways in mosquito and malaria work is reflected in the information collected by the National Malaria Committee on Engineering in 1930. Fifteen railway systems operating in the South and Southwest, with a total mileage of 74,898 miles supplied the information which is tabulated as percentage of the total miles:

Railways having some designated person assigned to mosquito and malaria control work	39	Per	cent
Railways applying oil in control of mosquitoes	60	"	"
Railways donating and applying oil	27	"	"
Railways doing right-of-way drainage control	88	"	"
Railways maintaining screened living quarters	85	"	"
Railways distributing quinine to employees	39	"	"
Railways distributing malaria educational bulletins	44	"	"
Railways responding to requests for aid in control work from cities, counties, or states	90	"	"

Appendix E

(9) DISINFECTANTS, FUMIGANTS, AND CLEANING MATERIALS

W. P. Hale, Chairman, Sub-Committee; W. R. Anthony, J. J. Laudig, O. T. Rees, H. W. Van Hovenberg, J. B. Young.

The subject assigned to the Committee has been deemed of sufficient importance to warrant extended investigations, since the subject covers a wide scope of varied materials of innumerable usages, and represents a considerable expenditure on the part of the various railways. For these reasons, the report for this year will consist of a general outline of the scope of the subject, a differentiation of the terms "disinfection", "fumigation" and "deodorization" and a digest of the more common compounds for the purpose required.

Any complete report on the subject must, of necessity, to be of any value to the members of the Association, contain definite instructions concerning the use of the varied materials, describe the particular compounds for each particular purpose, and detail methods for their successful use economically. This phase of the subject will be taken up in later reports of the Committee.

Disinfection

"Disinfection" means the destruction of the agents causing infection. An object is said to be "infected" when it is contaminated with disease producing bacteria. It is "disinfected" by destroying these bacteria, whether they are in the substance or on the surface of that object. Disinfection, then, deals only with destroying the vitality of those minute forms which cause disease. It does not mean the destruction of all the lower forms of animal and vegetable life that may be in or upon an object—that is, sterilization.

Considerable confusion exists between disinfectants and "deodorants". A deodorant is a substance which has the power to destroy or neutralize unpleasant odors, such as those arising from organic matter undergoing fermentation or putrefaction. Such substances must be carefully distinguished from disinfectants. Deodorants are not, necessarily, disinfectants, and disinfectants do not necessarily have an odor. No confidence can be placed on disinfectants simply because they smell of chlorine or carbolic acid, or possess the color of permanganate. Deodorants destroy smells; disinfectants destroy germs. Many of the disinfecting agents are also deodorants, but all deodorizing substances are by no means disinfectants. For example, charcoal will absorb the malodorous gases rising from rotting and fermenting organic matter, but it is inert so far as its power to destroy the cause of the processes is concerned.

Formalin and ozone, on the other hand, are true deodorants and disinfectants, as they combine with the organic matter to form new compounds which are both odorless and sterile. The volatile oils and other substances having a pungent odor are not deodorants, they simply cover up one smell with another.

The ideal disinfectant must first and foremost have a high germicidal power. It must not be rendered ineffective by the presence of organic matter; it must be reasonably stable, so as not to deteriorate under ordinary conditions; it must be soluble in water; it should be harmless to man and the higher animals; it should have the power of penetration; it should not corrode metals, nor bleach or rot fabrics, and finally it should be reasonable in price. Such perfect disinfectants are unknown.

The majority of the disinfectants sold to the public are mixtures of varying quantities of phenolic bodies, especially the cresols, with inert tar oils and an emulsifying

agent such as soap or tar, and sometimes resin or gelatin. These substances all possess a smell distinctive of carbolic acid and are effective germicides. Cresol is prepared from coal tar by collecting the distillates coming over between 140 degrees and 220 degrees C. and then purifying these distillates with solution of sodium hydroxide and hydrochloric acid.

In nature many forces are constantly at work to destroy infection and limit the spread of the communicable diseases. It is the duty of the sanitarian to encourage the use of these natural disinfecting agents; they are: dilution, sunlight, dryness and time. Sunlight is a great destroyer of germ life. Dryness, sunlight and cleanliness are the keynotes of sanitation in the modern acceptance of the term. Cleanliness is a very important ally to the work of disinfection. In fact it lies at the base of all our sanitation measures. Disinfection cannot compensate for the lack of cleanliness and ventilation.

For some time lime has been accepted as one of the best and cheapest disinfecting substances. It has been usually used either as lime or as chlorinated lime. The latter was used as a disinfectant and deodorant long before bacteriology was a science. It has a peculiar composition chemically and is somewhat unstable. Due to its affinity for moisture, which it slowly absorbs from the air, it soon becomes pasty and loses some of its chlorine. It should therefore be kept in airtight containers.

Chlorinated lime came into special prominence due to its use for the disinfection of drinking water and sewage. A surprisingly small amount will disinfect a large volume of water. A clean water may be rendered safe by the addition of 0.1 of a part of chlorinated lime (estimated as available chlorine) to 1,000,000 parts of water. For waters containing organic matter as much as 1 to 5 parts per million may be required.

Rideal and Walker* in 1903 introduced a method by which they proposed to determine and state in definite numerical terms the value of any disinfectant. This they called the "carbolic coefficient", because carbolic acid is taken as the unit of measurement against which the power of the other substances is compared. It is commonly known as the "phenol coefficient". This coefficient of any substance should be based upon the average of a large number of tests.

A low carbolic coefficient usually means a useless disinfectant. Formalin has a low coefficient, although formaldehyde is a potent germicide. This is due to the fact that the coefficient is based on formalin which contains only 40 per cent or less of formaldehyde. On the other hand it should be remembered that because a germicide has a high coefficient it is no absolute indication that it is a favorable disinfectant in practical work. There are many facts still to be considered, as noted in above paragraphs.

Liquid chlorine has largely replaced chlorinated lime in the disinfection of water and sewage since it has many advantages over the latter. The quantity used can be more accurately controlled; it has constant composition and does not produce sludge or increase the hardness of the water being treated. It is used also for removing taste and odors.

This gas is handled in gas tight pressure cylinders, takes up little space and the ordinary cost of application is less than chlorination with chlorinated lime.

The use of chlorination has been one of the blessings conferred on humanity, since its intelligent use in the field of water supplies has always resulted in marked decreases in typhoid fever and other intestinal diseases.

Formaldehyde in solution is known as formalin. This latter is a very valuable disinfectant with a wide range of usefulness in general practice. It is also a true deodorant. It is not injurious to most articles and not very poisonous. Rosenau states

* "The Standardization of Disinfectants", Journ. of Roy. San. Inst., 1903.

that "formaldehyde is the most generally useful and one of the best disinfecting gases we have."*

Fumigation

Fumigation consists of liberating fumes or gases with the object of destroying germs or vermin, insects, rats, mice, and other small animals, acting as carriers of infection, or destroyers of food products or other matter. The chief fumigants used are hydrocyanic acid gas, carbon bisulphide, chlorine, carbon monoxide, pyrethrum, formaldehyde, and sulphur dioxide. Fumigation cannot take the place of disinfection. It is chiefly useful in preventing the spread of insect-borne diseases, and the destruction or damage to food and other products.

Hydrocyanic acid gas is a cheap fumigant, probably the cheapest effective fumigant known. It is one of the most rapidly fatal poisons known to man. Because of this fact its use as a fumigant is attended by grave hazards to human life. This gas is our nearest approach to the ideal fumigant. It has practically no germicidal action, but is a very strong insecticide.

Sulphur dioxide, generally produced by burning sulphur, is the best gas in the matter of warning of its presence. It is the only nearly safe fumigant known, because in concentrations far below the quickly fatal level it causes severe irritation of the throat and persistent coughing. Sulphur fumigation has almost entirely been abandoned in this country because the gas penetrates so slowly and its results are unreliable. Sulphur dioxide tarnishes metals, rots fabrics, and bleaches pigments, especially when moist. Fumigation with sulphur dioxide may, however, be done with very little damage to property on dry days.

Pyrethrum powder is a popular and much used insect fumigant because it is comparatively cheap and non-poisonous to man and the higher animals. It is also non-corrosive, but unfortunately it has but a feeble action against roaches, vermin, flies, fleas, mosquitoes, etc. It has no germicidal action. Much of the pyrethrum on the market is impure, which further weakens what is at best a feeble insecticide.

Formaldehyde is an irritant gas, irritating the eyes, nose and throat. It is not dangerous to human life unless it is in enormous concentration and then only after long exposure. Rosenau states that "it is not very toxic to higher forms of animal life, but it is the leading germicide. It is not an insecticide. In the strongest concentrations possible it has no effect on roaches, bedbugs and other strong insects."*

Three substances have lately been developed as fumigants which will probably become widespread in use. These are ethylene dichloride, ethylene oxide, and carbon dioxide. The first named is generally mixed with carbon tetrachloride to remove the fire hazard. These fumigants are much less poisonous than hydrocyanic acid and must be used in much higher concentrations. They are relatively slow in their action, and are relatively more poisonous to insects and warm-blooded animals. These properties permit fumigation with reduced hazard to human life.

In many instances certain types of fumigation are required by Federal statute. One instance is that of cotton freight cars infected with Mexican pink bollworm, a very serious pest to cotton. Several years ago inspection revealed that frequently certain types of freight cars returning from Mexico were likely to be contaminated with cottonseed, and if the cottonseed originated in areas in Mexico where the pink bollworm occurred it was often infested with the larvae of this insect. To guard against further entry of the pink bollworm into this country provision was made for the cleaning of all cars found to be

* Rosenau "Preventive Medicine and Hygiene".

contaminated with cottonseed, and, as an added precaution, fumigation was required to take care of any larvae which might be present in cottonseed that had escaped detection in the floor, cracks in the walls, and other out-of-the-way places in the cars.

The first fumigation on the Mexican border was performed by the old so-called "pot method" whereby hydrocyanic acid gas was generated inside the car from sodium cyanide, sulphuric acid and water. This method at its best was not entirely satisfactory. When the fumigations were numerous considerable work was involved in attempting to make the cars tight, and naturally the fumigation was limited to box cars only. It was also impossible to reach any cottonseed which was present on the trucks or attached to the outside of the cars. Frequently cars were received in such bad condition that it was impossible to make them air-tight enough for the fumigation to be effective. In order to overcome these difficulties specially designed fumigation houses were constructed. The first car fumigation houses were built during 1919. At the present time there are six such houses along the Mexican border, with capacities varying from 20 cars or less. These houses are constructed of brick, and are so divided by sliding doors that any number of cars from one to the maximum capacity of the house can be accommodated. For several years liquid hydrocyanic acid has been used as a fumigant and satisfactory results have been obtained.†

Some idea of the vast scope of the assigned subject may be obtained from the following outline of correlated purposes for which disinfectants, fumigants, deodorants, and cleaning materials are used on railways, and on which detailed report will be prepared before conclusion of the assignment:

1. Disinfection and/or deodorization of passenger cars, cattle cars, cattle pens, poultry cars, cotton cars, copra and bone cars.
2. Fumigation of grain cars, grain elevators, camp cars, passenger equipment, hotels, eating houses, grain houses, etc.
3. Car cleaning, cuspidor cleaning, washing floors and woodwork and windows, drinking water disinfection, sterilizing water tubs, cisterns or tanks.
4. Cleaning and deodorizing cars or buildings used in handling fish, milk and cream, dressed and live poultry, etc.

All these matters are pertinent to the assigned subject of "Disinfectants, Fumigants, and Cleaning Materials," and will be discussed in future reports.

† Division Foreign Plant Quarantine—Wash., D. C.

REPORT OF COMMITTEE XXII—ECONOMICS OF RAILWAY LABOR

Lem Adams, *Chairman;*
C. W. Baldridge,
W. R. Bennett,
A. E. Botts,
H. A. Cassil,
J. I. Catherman,
C. S. Colvin,
J. F. Dobson,
Wm. Elmer,
J. A. Gorr,
Paul Hamilton,
W. S. Hanley,
H. H. Harsh,
A. C. Harvey,
H. I. Hoag,
C. H. R. Howe,
E. T. Howson,
C. A. Johnston,
C. R. Knowles,
G. M. Magee,
G. M. O'Rourke,
J. A. Parant,
F. S. Schwinn, *Vice-Chairman;*
J. C. Patterson,
H. E. Perkins,
F. R. Rex,
H. M. Righter,
H. M. Stout,
F. M. Thomson,
J. G. Wishart,
C. R. Wright,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully presents herewith report covering the following subjects:

(2) Analysis of operations of railways that have made marked progress in the reduction of labor required in maintenance of way work (Appendix A).

(4) Methods of reducing work-train service and economies in maintenance expenses effected thereby (Appendix B).

(5) Programming of bridge and building work (Appendix C).

(6) Revised plans for outfit cars for maintenance of way employees (Appendix D).

(8) Gang organization and methods of performing maintenance of way work, including revision of time studies now in the Manual (Appendix E).

Progress is reported on Subjects 1, Revision of Manual; and 7, Economics of methods of weed killing.

Action Recommended

(1) That the report under Appendix A be received as information and the subject continued.

(2) That the report under Appendix B be received as information and the subject be discontinued.

(3) That the report under Appendix C be approved as recommended practice and printed in the Manual, and the subject be discontinued.

(4) That the report under Appendix D be accepted as information, the conclusions and plans be adopted as recommended practice and printed in the Manual.

(5) That the report under Appendix E be received as information and the subject continued.

On Subject No. 3, Effects of recent developments in maintenance of way practices on gang organization, the Committee is unable to develop any additional information at the present time and recommends that the subject be discontinued for the present.

Respectfully submitted,

The Committee on Economics of Railway Labor,

Lem Adams, *Chairman.*

Bulletin 362, December, 1933.

Appendix A

(2) ANALYSIS OF OPERATIONS OF RAILWAYS THAT HAVE MADE MARKED PROGRESS IN THE REDUCTION OF LABOR REQUIRED IN MAINTENANCE OF WAY WORK

J. A. Parant, Chairman, Sub-Committee; W. R. Bennett, H. A. Cassil, J. F. Dobson, A. C. Harvey, E. T. Howson, C. A. Johnston, C. R. Knowles, J. C. Patterson.

In November, the Committee made its second inspection trip over the Lehigh Valley Railroad.

Considerable additional information on the assignment has been gathered, but not in form to present to the Association this year as a supplement to the 1930 report.

Appendix B

(4) METHODS OF REDUCING WORK-TRAIN SERVICE AND ECONOMIES IN MAINTENANCE EXPENSES EFFECTED THEREBY

G. M. O'Rourke, Chairman, Sub-Committee; Wm. Elmer, J. A. Gorr, W. S. Hanley, H. H. Harsh, A. C. Harvey, E. T. Howson, F. M. Thomson.

Among the means to effect economy and increase efficiency that have been investigated by the Committee is the reduction in work-train service for maintenance of way operations. That some reduction has been effected in recent years is generally known. The magnitude of this reduction is, however, not widely appreciated. The total work train mileage of the Class I railways of the United States, as compiled by the Interstate Commerce Commission, is as follows:

Year Ending December 31	
1916	46,728,640
1917	44,737,643
1918	45,039,419
1919	36,705,124
1920	41,494,199
1921	25,672,043
1922	27,369,588
1923	37,384,812
1924	32,489,978
1925	33,114,358
1926	37,279,616
1927	36,531,830
1928	33,236,462
1929	35,775,192
1930	24,079,859
1931	13,960,642
1932	8,066,621

The figures for 1930, 1931 and 1932 were obviously influenced by the curtailment of operations, as were also those for 1921–1922. If the figures for these years be ignored, and consideration be confined to the more normal years of 1916–1920, inclusive, and 1923–1929, inclusive, the trend can be determined more accurately. Thus, in the five-year period from 1916 to 1920, the average work-train mileage was 42,941,206, while in the seven years from 1923 to 1929, inclusive, the average was 35,101,949. In other words,

in this average interval of eight years, the decrease was 18 per cent, or at the average rate of 2¼ per cent per year.

The above figures include all work train mileage, maintenance of way and otherwise. If it were possible to segregate that employed in maintenance of way operation, it would be shown that the decrease here is relatively greater than the average shown above. The figure given is sufficient, however, to show the trend.

To determine how this has been accomplished, the following questionnaire was sent to 47 railroads of the United States and Canada. Twenty-six replies were received:

1. What reductions have you made in work-train service for maintenance of way operations during the last ten years?
2. What measures have you initiated to effect this reduction:
   (a) Through the use of track motor cars;
   (b) Through the use of self-propelled cranes, pile drivers, etc.;
   (c) Through the more extensive use of local freight or other revenue trains;
   (d) Through the use of off-track equipment;
   (e) Through other measures.
3. For what operations are you employing these various measures;
   (a) With what results?
4. What further substitutions of work-train service do you believe are feasible?
5. For what operations is work-train service still essential?
6. To what extent and in what ways is the use of self-propelled equipment restricted by statute or agreements with employees?
7. How is the ordering out of work trains controlled?

Reductions of Work-Train Service

Reductions were reported by 25 roads in the use of work trains for maintenance of way operations during the last ten years. One road reported no reduction except that such as was incidental to less work being done this season than in some years past.

Two carriers reported a 75 per cent reduction, one road 72.7 per cent reduction in number, and 73.4 per cent in cost during past seven years; one road 55 per cent, two 50 per cent, one 40 per cent, one 22 per cent and two 20 per cent reduction in work trains during the last ten years.

During the last four years the great reduction in work-train service has been due to curtailed maintenance of way operation. Nevertheless, the use of work trains has been curtailed by very close scrutiny of the operations that had heretofore been handled by special work trains, and other service substituted.

The principal means of reducing work-train service, in reply to inquiry No. 2, are listed below:

Measures Initiated	*Railroads Reporting*
Use of local freight trains	22
Track motor cars	18
Self-propelled cranes	18
Light extras—to balance power	13
Self-propelled pile drivers	13
Off-track equipment	11
Cooperation of transportation department	4
Highway trucks	4
Closer planning and supervision	3
Self-propelled ditchers	3
Narrow-gage cars ditching cuts	1
Creosoted cross-ties and switch-ties	1
Supply train	1
Contracting work to outside parties	1
Use of switch engines in terminals	1
Self-propelled derricks	1
Caterpillar trucks and trailers	1

Practically all of the 22 railroads reporting state that special attention has been given to the use of local freight and other slow revenue trains for the distribution of material along the railroad. In many cases ditching machines were used for several hours daily, where local freight did not require full time to make the assigned run.

By consolidating work of different kinds in certain territories or by holding loads of ballast, etc., until enough cars are accumulated for more than one day's consecutive work-train service, and by providing more than one day's work in the same territory on many railroads, engine and crew may be tied up near the work and considerable deadhead payments can be avoided as compared with having several work-train days at different periods.

Balancing Power

Many railroads have made full use of surplus power in direction of light tonnage for doing work and find this to be one of the most fruitful sources of work train savings. By keeping in close touch with the transportation department and by proper planning of the work, large savings are being effected by using power in the direction of light tonnage.

Cooperation Between Maintenance of Way and Transportation Departments

Four railroads put particular stress on cooperation between the maintenance of way and the operating departments. One of these reported 75 per cent reduction during the past decade by "closer planning and supervision and through better cooperation of the operating department." Another large carrier in the west states that probably the most important factor in reducing work-train service has been the more careful planning and scheduling of the work, enabling more work to be done with less train service.

Distribution of Materials

A railroad serving a congested industrial and mining territory in the east advises that the programming of maintenance work requiring work-train service is highly important. This practice permits the establishment of definite schedules for receiving and distributing materials, for ditching and pile driving, and consequently is a very important factor in preventing waste, and in avoiding duplication of effort. With knowledge of the work planned through the year, the required number of men may be selected and kept in work-train service. Outfit cars are provided, and as a unit they achieve greater efficiency than could ever be attained by "picking up" a section force or a different gang each day. Supervision of work-train service on this railway is supplemented by a staff of technically trained young men, familiar with the maintenance program, whose duty it is also to keep cost records of all work. The benefit of economies thus effected is also reflected in transportation and operating costs.

A western trunk line distributed cross-ties over its entire main line and important branch lines during this year by the use of work train, using an assigned crew. The camp cars were kept in the work train at all times, and by having cross-ties set out in cars in quantities of 10 to 20 cars at a time on sidings where there would be no back-haul. When the assigned trains were operated, the crew was able to tie up at night, and started from that point the next day.

The work was planned for a continuous operation, beginning at one end of the line and working through to the other end and diverging to branch lines in the manner to give the best possible working time. This operation required a lot of planning in advance in order that the ties would arrive at the location where needed in sufficient quantity and sufficiently in advance to prevent delay to tie distribution crew and at the same time avoid unduly tieing up equipment.

Use of Track Motor Cars

The use of track motor cars to avoid or supplement work train service as reported by 20 railroads is as follows:

To distribute track ties from storage piles to point of use.

To distribute repair rails, frogs, switches and other track materials used in repairs.

For the distribution of materials used in repairing washouts; particularly sand bags, riprap, etc.

To transport large extra gangs to and from work.

To tow transverse fissure detector car.

To transport broken or other defective rails and scrap to a central point.

For moving tie tamping and welding equipment and many other operations that formerly required work trains.

Use of Self-Propelled Equipment

A large number of railroads reporting advise that the use of self-propelled cranes, pile drivers, etc., has greatly reduced requirements for work trains. These machines are used in many ways; some of the most general uses are as follows:

A locomotive crane is used to take out two cars of rail at a time, and distribute the rail for laying, where distance from sidings is not too great, also pickup rail and fittings after relay.

The self-propelled crane is also used with a clamshell bucket and two dump cars to load rock and similar classes of work.

These cranes are used extensively for handling heavy material about shops, material yards, and reclamation plants.

The self-propelled ditcher is extensively used for cleaning cuts, using two dump cars where material can be disposed of by making only short runs.

Self-propelled pile drivers and erection derricks are very extensively used and have largely displaced the use of work trains in pile driving and heavy bridge erection.

Delivery and Pickup of Materials and Supplies in Terminals

The delivery and pickup of materials and supplies in terminals, and for a distance of several miles out on the line, is now being handled largely by trucks where this work was formerly done by work trains. The use of tractors is becoming more general in the movement of heavy equipment and materials from point to point.

One railroad reports that the use of a caterpillar dragline has eliminated fifteen days' work-train service from a 45-day job.

With reference to other means of reducing work-train service, a railroad serving New York and the New England States reports a 30 per cent reduction during the past ten years through the use of motor trucks on concrete highways.

Another road reports that the regular supply train handles all work train duties set up for it.

A southwestern railroad reports that auto trucks, some with special equipment, have been found of great value and have been given extended use during the past ten years in connection with the maintenance of electric lines on streets, both on track and overhead. These trucks are used to move frogs, rail, ties, tie tamping and welding equipment, etc., the same as motor cars and trailers are used for this service on tracks not on streets.

Another road has found it possible, especially on light traffic lines, to lineup cars behind the caboose and cut them off on the main track, under flag protection, at the place where contents are to be unloaded. The empties are pushed into the clear by the next train. It was formerly the practice on this railroad to unload concrete, sand and

gravel by clamshell or by hand from gondola coal cars. They have followed the practice lately of loading the material in hopper cars and plowing it off in the track at the bridge site in a fraction of the time formerly taken. A slight excess of material is ordered.

One railroad reports the use of narrow-gage dump cars in cuts requiring constant ditching. Work train expense can sometimes be avoided by spotting cars on sidings and yard tracks, engine leads and other tracks until material is unloaded. The same road has found it practicable, in some places, to use caterpillar bulldozers in lieu of ditchers.

These substitute measures are being employed on work formerly requiring work train service.

Jobs handled by equipment of various kinds, resulting in reduction of work train expense are: Erecting signals, placing heavy riprap, picking up scrap with magnet attached to self-propelled cranes, and distributing station coal by truck from one central set-out point.

Mowing, Discing and Burning Weeds

Mowing, discing and burning weeds by self-propelled machines are now extensively used in place of chemical spraying with work train.

Oiling Roadbed

Oiling roadbed, to keep down dust, with self-propelled oiling machines are now used. This was formerly done by fastening spray to tank car moved by work train.

Discussion

It is claimed that all of these operations described in the foregoing have resulted in saving money, reducing obstruction of main tracks, and effecting more prompt delivery of men and materials. Work train time is reduced and work is done at lower cost. A saving of materials is reported and in many instances a more workmanlike job is secured.

Concerning the further substitution for work train service now considered feasible, the consensus of replies indicates the more extensive use of off-track equipment, particularly motor trucks and caterpillar equipment.

Work-train service appears to be still essential where materials to be handled are of such quantity, weight or kind that there is no economy in attempting to handle them by any other means. Such materials are rail, ballast, ties where more economical to distribute than store on station grounds, cinders and refuse, telegraph poles, cast iron and concrete pipe, etc.

On large construction or rehabilitation jobs it may be more economical and practicable to move large camp outfits, derricks and pile drivers in work trains.

Ditching with steam shovel type or spreader type ditchers, eradicating weeds with chemical outfits, oiling roadbed with spray equipped tank cars, handling snow plows, large ballast cleaning machines, moving dirt in large quantities for grading sites for new construction and handling pile drivers at bridges a considerable distance from point of clearance are operations requiring work train service.

Emergencies such as washouts and fires and where quick clearance of trains is required, it is almost always considered necessary to have work-train service.

The necessity for much work train use results from local freight trains being taken off or in some territory running at night and the extreme difficulty of handling outfits in heavy tonnage trains, which in certain territory are often the only trains available. Ordinarily, operations such as those outlined that require work-train service, if there are

many men involved, can be performed more economically for the railroad if it is done by work-train service than to have men waiting to use revenue trains.

Where heavy material in any quantity is handled, it may be found possible to perform the work in such a way that work-train service of itself is not essential, but any substitute must have more or less the characteristics of a work train and may be equally expensive.

Restriction of Movements of Equipment

The use of self-propelled equipment is restricted by statute in North Dakota, and, on the railroad making reply to this question, by agreement with employees to the extent that pilot conductor shall be employed when equipment which cannot be lifted on and off the track is used. The agreement with the employees is limited to the handling of standard cars with self-propelled cranes. For weed mowing machines, weed burners, etc., they operate on train orders without pilot conductors.

Self-propelled equipment is restricted by statute in Wisconsin to the extent that a full crew is required where self-propelled machines are used outside of terminals, regardless of whether or not a locomotive is used with them.

The use of self-propelled equipment is restricted in California by Assembly Bill No. 927, Chapter 501, and amendments approved May 25, 1915. On lines with more than four trains per 24 hours, self-propelled equipment covered by the Act must operate within one-half mile of a set-out track or be in charge of a train crew.

In Ohio, railroads are prohibited by statute from switching cars, that is, coupling or uncoupling a self-propelled crane. This applies whether working on the main line or on a siding. On this railroad, operating in Ohio, in most cases where self-propelled equipment is working on the main line, a full crew is required to protect the movement.

A road serving the southwest reports that the use of self-propelled equipment is restricted by statute only as to air brakes, couplers and other M.C.B. devices. Agreements with employee organizations provide that a qualified conductor shall be used as pilot in handling and using self-propelled equipment on running tracks.

Another railroad advises that, under their wage agreements, they are required to have a crew of not less than one conductor and two brakemen where necessary to work under train orders.

A southern road reports that pile drivers and locomotive cranes which cannot be readily removed from the track are provided with a crew when required to work more than one-half mile from a siding.

On a large eastern system, self-propelled equipment may be used on sidings and in yards with only maintenance personnel, but train crews are required when operating on main line.

On one large railroad, self-propelled equipment is restricted by the fact that train service employees must be given the opportunity to qualify on such equipment when used in the movement of cars in maintenance of way service. Movement over main running tracks must be protected by qualified train service employees and such equipment must be operated by qualified work equipment operators.

Three eastern railroads state that while they are not restricted by statute, it is necessary to use a full flagging crew when main tracks are occupied in order to provide protection.

Statutes and working agreements requiring train crews destroy savings that otherwise would be secured by the use of self-propelled equipment.

One railroad advises that the operation of self-propelled equipment between any two stations is permitted without the services of a conductor pilot or flagman. In such

cases employees in maintenance gangs perform necessary flagging under the rules. Where such equipment is moved beyond the territory lying between two stations immediately adjacent, a conductor pilot is required and in some instances, when desirable from the railroad's standpoint, in order to facilitate the movement of the equipment, a flagman from the train service is also assigned to the equipment.

When it is definitely determined that a work train or work-train crew is required, the general practice is for the Division Engineer to make a request upon the Division Superintendent, either direct or through the Chief Dispatcher. On some roads, however, approval must be issued by the Engineer Maintenance of Way or Chief Engineer before a work train is authorized.

Conclusions

As a result of its study, the Committee has reached the following conclusions:

1. That maintenance of way operations should be carefully planned to reduce the number of work trains required.

(a) By so programming the work as to permit it to be done in consecutive order and eliminate duplicate movements.

(b) By utilizing spare time of light extra and local trains.

(c) By having a thorough understanding by all concerned in the transportation and maintenance departments regarding work to be done and time required to do it.

(d) By insuring that locomotives assigned have sufficient power to handle the work.

(e) By loading materials in suitable cars.

(f) By selection of the proper type of crane for unloading and loading rail and having a properly organized gang experienced in the kind of work being done.

(g) By lining up work to be done in consecutive order to avoid backup movements and having sufficient work for a full day's work-train service.

(h) By the extended use of motor cars to handle men and material.

(i) By the use of other self-propelled equipment wherever suitable.

(j) By further development and use of off-track equipment.

Recommendation

Your Committee recommends this report be accepted as information and the subject discontinued.

Appendix C

(5) PROGRAMMING OF BRIDGE AND BUILDING WORK

A. E. Botts, Chairman, Sub-Committee; W. R. Bennett, C. S. Colvin, J. F. Dobson, Paul Hamilton, H. E. Perkins, F. R. Rex, H. M. Righter, C. R. Wright.

1. Secure by careful field inspection, by competent representatives, first-hand information of the work to be performed and the material required. This inspection to include:

(a) All material required for the ensuing year.

(b) Lumber required for the second year, which will necessitate 12 months seasoning in advance of treatment, such as oak bridge ties.

2. Classify each of the projects, at time of field inspection, by one of the three following designations:

(a) Additions to and Betterments of Existing Facilities
(Work entailing charges to Capital Account)

(b) Maintenance of Existing Facilities
(Work of major importance)

(c) Maintenance of Existing Facilities
(Work of minor importance)

3. Assign an item number to each project for reference purposes.

4. Furnish Supply Department with forecast of materials required, separating as outlined under sections (a) and (b) of paragraph 1.

At this point it is necessary to separate the work into two groups:

Maintenance of Existing Facilities	*Additions to and Betterment of Existing Facilities*
1. Prepare estimate of the cost of performing the work on each individual project.	1–A. Prepare detail plans and estimates of cost of each individual project.
2. Prepare schedule, distributing the estimated costs by months.	2–A. Prepare schedule, distributing the estimated cost by months.
3. Prepare annual forecast of Maintenance of Way expenses and secure authority for performance of the work.	3–A. Prepare annual forecast of Capital Account projects and secure authority for performance of the work.
4. Furnish local officers with copy of schedule and authorize the program.	4–A. Furnish local officers with copy of schedule, detail plans and "Authority For Expenditure".
5. Order material for the various projects in accordance with details of the program.	5–A. Order material for the various projects in accordance with detail plans.
6. Secure monthly or semi-monthly report of progress of the work.	6–A. Secure monthly or semi-monthly report of progress of the work.
7. Secure accounting record of charges made to each project.	7–A. Secure accounting record of charges made to each project.

RECOMMENDED FORMS

Form No. 1—Inspection for Annual and Structure Program

This form has been prepared for the recording of data obtained by the field inspection.

Each project requiring attention should be listed and a complete bill of material made.

Each project should be classified as "A", "B", or "C", as follows:

Class "A" Improvements to Existing Facilities, Additions and Betterment work will require securing authority for capital expenditures.

Class "B" Maintenance of Existing Facilities, Maintenance work of major importance.

Class "C" Maintenance of Existing Facilities, Maintenance work of minor importance.

Upon completion of the field inspection, original of Form 1 should be forwarded the Chief Engineer or Engineer Maintenance of Way for preparation of annual budgets, copy to be retained by local officer.

FORM I

THE NORTH AND SOUTH RAILROAD

INSPECTION FOR ANNUAL BRIDGE AND STRUCTURE PROGRAM 19___

_____DIVISION;_____SUB DIVISION; BRIDGE STRUCTURE } NO._____

LOCATION AND NAME_____

_____

CLASS OF WORK_____

DESCRIPTION OF WORK	MATERIAL REQUIRED			MAN HOURS
	DESCRIPTION	QUANTITY	SPEC.	

REMARKS:

Form No. 2—Annual Bridge and Structure Program

All projects reported on Form No. 1 as Class "A" should be listed in the order of their importance on Form No. 2 and each project given an item number for reference purposes.

All projects reported on Form No. 1 as Classes "B" and "C" should be listed in the order of their importance on Form 2 and each project given an item number for reference purposes. Class "B" projects should be given preference, as a budget curtailment would result in the elimination of Class "C" projects first.

Form No. 2 should be prepared by operating divisions as the information contained in the columns "Estimated Cost" and "Schedule of Work (Line E)" should be used in the preparation of annual forecasts of Maintenance of Way expenditures and for the setting up of monthly allowances.

The estimated cost of performing work on each project should be determined by the Chief Engineer or the Engineer Maintenance of Way, or secured from local officers, and inserted in column captioned "Estimated Cost". These estimated amounts should also be distributed to the various months in the columns captioned "Schedule of Work and Monthly Expenditure". The schedule estimate should be identified by using the letter "E".

Copy of Form No. 2 should be furnished the division maintenance officers to permit their ordering necessary materials and the scheduling of the work by forces.

In some cases it will be found desirable to have the costs of various classes of work on a single project kept separate. When this is desirable, an additional reference number may be assigned under "Code Reference".

Form No. 3—Annual Bridge and Structure Forces Program

Division maintenance officers upon receipt of Form No. 2, "Annual Bridge and Structure Program", should prepare schedule of work to be performed by each force.

This schedule should be prepared on Form No. 3, "Annual Bridge and Structure Force Program" and should agree in detail with the projects as listed on Form No. 2, "Annual Bridge and Structure Program".

Division maintenance officers should furnish each foreman with copy of the schedule of work to be performed by his force, and should also arrange for the ordering of the material.

Progress Report

Semi-monthly or monthly Progress Reports can be used to a considerable advantage for the purpose of keeping Maintenance of Way officers posted on the status of work on each project.

This information can well be furnished in typed statement form by reporting the following:

Division
Name of foreman
Item number
Code number
Location
Date started
Man-hours
Per cent scheduled for month
Per cent completed during month
Per cent scheduled to date
Per cent completed to date
Date completed
Remarks: (Reason for delays, etc.)

Progress as shown on this report should be posted to Form 2, "Annual Bridge and Structure Program", and to Form 3, "Annual Bridge and Structure Force Program," in the proper column (month) under "Schedule of Work and Monthly Expenditures", and should be identified by the letter "G".

Report of Expenditures

To permit complete record being maintained on Form No. 2, "Annual Bridge and Structure Program", and to Form 3, "Annual Bridge and Structure Force Program," a monthly statement of charges should be secured from the accounting records.

The form should include the following information:

Division
Item number
Code number
Location
Labor expenditure
Material expenditure

Costs as shown on this report should be posted to Form No. 2, "Annual Bridge and Structure Program," and to Form 3, "Annual Bridge and Structure Force Program," in the proper column (month) under "Schedule of Work and Monthly Expenditure", and should be identified by the letter "F".

FORM 2

THE NORTH AND SOUTH RAILROAD

ANNUAL BRIDGE AND STRUCTURE PROGRAM

CLASS_____ (A-B-C)

YEAR_____

DIVISION_____

ITEM NUMBER	CODE NUMBER	BRIDGE OR STRUCTURE NUMBER	LOCATION AND NAME	DESCRIPTION OF WORK	MATERIAL REQUIRED			REQN. REFERENCE		ESTIMATED COST				SCHEDULE OF WORK AND MONTHLY EXPENDITURE (E-ESTIMATE A-ACTUAL P-PROGRESS COMPLETE)																								FINAL COST			DATE	
					DESCRIPTION	QUANTITY	SPEC.	NUMBER	DATE	DELIVERY DATE	LABOR		MATERIAL	TOTAL	JAN.		FEB.		MARCH		APRIL		MAY		JUNE		JULY		AUG		SEPT.		OCT.		NOV.		DEC		LABOR	MTL	TOTAL	STARTED	COMP'D
											MAN HRS	AMOUNT			LABR	MTL	LABR	MTL	LABR	MTL	LABR	MTL	LABR	MTL	LABR	MTL	LABR	MTL	LABR	MTL	LABR	MTL	LABR	MTL	LABR	MTL	LABR	MTL					

FORM-3

THE NORTH AND SOUTH RAILROAD

ANNUAL BRIDGE AND STRUCTURE FORCE PROGRAM

YEAR_____

DIVISION_____

FOREMAN_____

ITEM NUMBER	CODE NUMBER	BRIDGE OR STRUCTURE NUMBER	LOCATION AND NAME	DESCRIPTION OF WORK	SCHEDULE OF WORK AND MONTHLY EXPENDITURE (E-ESTIMATE A-ACTUAL P-PROGRESS COMPLETE)																								TOTAL	
					JAN.		FEB		MARCH		APRIL		MAY		JUNE		JULY		AUGUST		SEPT		OCT		NOV		DEC			
					M. HRS.	AMT.	M. HRS	AMT	M. HRS.	AMT.	M. HRS	AMT.	M. HRS.	AMT.	M. HRS.	AMT.	M. HRS.	AMT.	M. HRS.	AMT.	M. HRS	AMT.	M. HRS.	AMT.	M. HRS	AMT	M. HRS.	AMT.	M. HRS.	AMT.

Appendix D

(6) REVISED PLANS FOR OUTFIT CARS FOR MAINTENANCE OF WAY DEPARTMENT EMPLOYEES

G. M. Magee, Chairman, Sub-Committee; William Elmer, H. I. Hoag, J. G. Wishart.

In his address before the Twentieth Annual Convention of the A.R.E.A., President C. A. Morse gave the following quotation from Frances A. Kellor, at that time Assistant to Chairman, Immigration Committee, Chamber of Commerce of the United States:

"Where do we find ourselves today in handling labor? All the way from the ditched box-car, vermin-ridden and disease-laden, housing workmen neglected and isolated, at one end of the scale, to the Ford plant at the other."

With reference to the above quotation, the President commented:

"We have made some advances during the past two or three years toward improving the situation on the railroads. We must go at it on a much larger scale, not from a humanitarian point of view but from a business point of view."

In the Proceedings for this same year, Committee XXII reported on "Typical Plans for Housing Labor". This report contained typical plans for the construction of camp or outfit cars and these plans were very beneficial in bringing about an improvement in the sanitation and comfort of outfit cars for floating gangs.

Since 1919 railways have shown a continued interest in improving the living conditions of outfit cars. In recent years this subject has increased in importance due to the tendency towards increasing use in railway maintenance work of specialized gangs equipped with labor-saving equipment and employing in many instances men accustomed to higher standards of living. On some roads where the standard of living to which the men were accustomed have justified it, outfit cars have been provided from retired passenger equipment and very completely equipped with comfortable beds, running water, lavatories, shower baths, sanitary toilets, electric lights, recreation rooms, refrigeration and generally improved living conditions.

Revision of the earlier plans for outfit cars was assigned to this Committee. This Committee requested standard plans of outfit cars from a number of roads and these plans were kindly furnished. After careful study, the following plans have been prepared to represent the most satisfactory general arrangement and equipment of outfit cars for maintenance of way work. It is realized that in almost every condition some special consideration must be given to most efficiently meet the individual problems. For that reason, these plans have been prepared for general use in such a manner that suitable revisions may be easily made to suit the required standard of living, size of gang, type of work, or other specific considerations.

Reference is made to Railway Engineering and Maintenance, page 248, 1929, for photographs of these camps.

The following points should be considered by the individual road in the design of outfit cars:

(1) The standard of living conditions provided in outfit cars should be consistent with that to which the occupants are accustomed so the occupants will enjoy their quarters on the one hand and the quarters will not be subject to abuse by the occupants on the other.

(2) More comfortable living conditions may justifiably be provided for the gangs employed continually the year round than for gangs employed in seasonal work.

(3) The cars should be well constructed and properly insulated for economy in heating and comfort in both winter and summer.

(4) Platform type steps at the ends of the cars are desirable both as a matter of convenience and safety.

(5) The interior finish and painting should facilitate cleaning and sanitation.

(6) Good ventilation and comfortable beds in sleeping rooms will materially improve the day's work.

(7) Sanitation and convenience in the kitchen and dining room should be of major consideration.

(8) Electric lights, running water, toilet facilities and adequate heating will aid materially in retaining desirable men in service.

(9) Proper refrigeration should be provided to prevent loss of foodstuffs and to safeguard health.

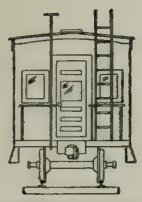
(10) Cars selected for use as outfit cars should have underframes and superstructure of sufficient strength to enable them to be handled any place in train without danger of buckling.

Conclusions

The accompanying drawings show typical plans for the construction and arrangement of:

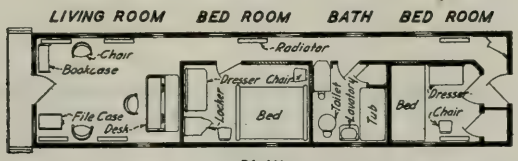
Foreman car
Kitchen and dining car
Recreation car
Sleeping car
Water and fuel car

for use in the maintenance of way, using either freight or passenger equipment. Your Committee recommends that living conditions of outfit cars be made as comfortable and sanitary in accordance with these general plans as economic considerations permit.



END ELEVATION

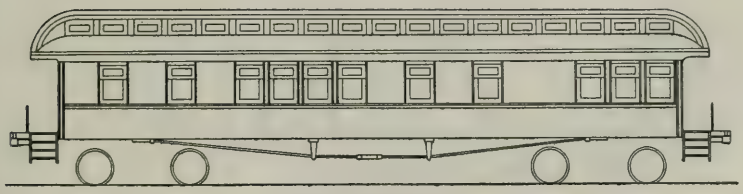
SIDE ELEVATION



PLAN

OUTFIT CARS-FREIGHT EQUIPMENT

TYPICAL PLAN FOR FOREMAN CAR



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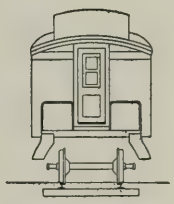

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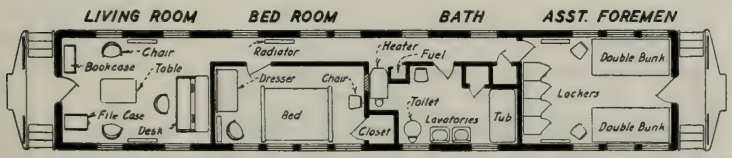
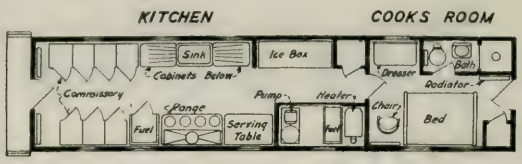


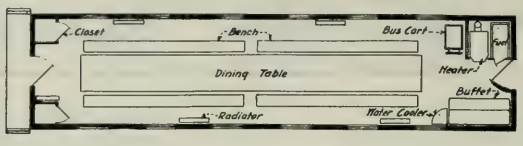
PLAN

OUTFIT CARS-PASSENGER EQUIPMENT

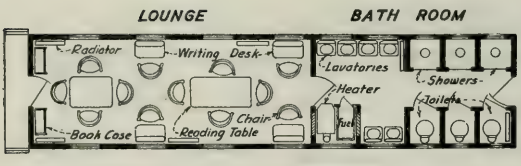
TYPICAL PLAN FOR FOREMAN CAR.



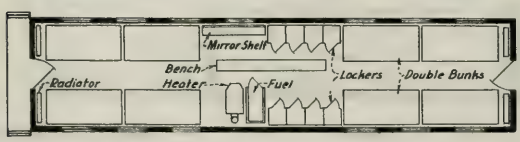
TYPICAL PLAN FOR KITCHEN CAR



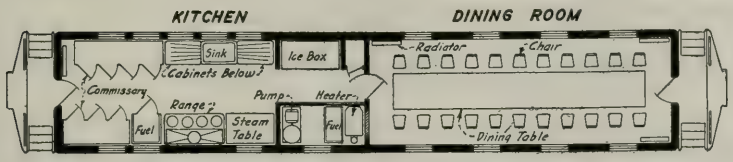
TYPICAL PLAN FOR DINING CAR



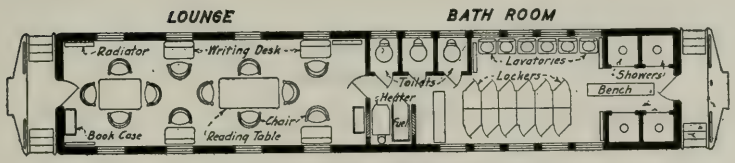
TYPICAL PLAN FOR RECREATION CAR



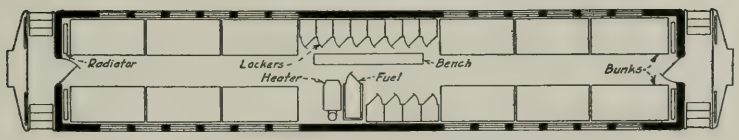
TYPICAL PLAN FOR SLEEPING CAR



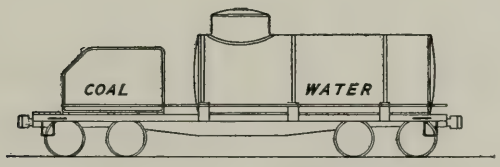
TYPICAL PLAN FOR KITCHEN AND DINING CAR



TYPICAL PLAN FOR RECREATION CAR



TYPICAL PLAN FOR SLEEPING CAR



TYPICAL WATER AND FUEL CAR

Appendix E

(8) GANG ORGANIZATION AND METHODS OF PERFORMING MAINTENANCE-OF-WAY WORK, INCLUDING REVISION OF TIME STUDIES NOW IN THE MANUAL

C. H. R. Howe, Chairman, Sub-Committee; Paul Hamilton, H. I. Hoag, C. A. Johnston, G. M. Magee, J. A. Parant, H. M. Righter.

The Committee has continued its investigation of the time studies now remaining in the Manual with view of revising such of them as are not representative of modern practices.

Considerable information has been secured on the subject of mechanical tie tamping organizations, but there are now in process of development certain innovations in the design of equipment used on this class of work that should prove to be of value. As soon as it is practical to do so, this information will be embodied in a report for the consideration of the Association.

Recommendation

It is recommended that the subject be continued.

REPORT OF COMMITTEE II—BALLAST

A. P. Crosley, *Chairman;*
A. L. Bartlett,
G. J. Bell,
C. J. Coon,
M. I. Dunn,
H. F. Fifield,
W. L. Foster,
J. J. Gallagher,
A. T. Goldbeck,
C. G. Grove,
Daniel Hubbard,
A. A. Johnson,
A. D. Kennedy,
O. N. Lackey,
H. M. Long,
P. J. McCarthy,
W. W. Patchell,
J. M. Podmore,
C. P. Richardson,
H. M. Righter,
P. T. Robinson,
W. A. Roderick,
C. B. Stanton, *Vice-Chairman;*
W. J. Shaw, Jr.,
A. B. Shimer,
J. W. Stone,
Stanton Walker,
C. S. Wicker,
J. B. Wilson,
A. H. Woerner,
A. O. Wolff,

Committee.

To the American Railway Engineering Association:

Your Committee respectfully presents herewith its report on the following subjects:

(1) Revision of Manual.

(2) Specifications for prepared gravel ballast, including best method of testing for hardness, abrasion and resistance to weathering (Appendix A).

(3) Specifications for stone ballast, including best method of testing resistance to weathering (Appendix B).

(4) Comparative costs of maintaining track on various kinds of ballast (Appendix C).

(5) Effects of different kinds of ballast on life of ties, on life of rail and upon rail failures, particularly as between gravel and crushed stone ballast. Committee reports progress.

(6) Determine proper depth and kind of sub-ballast (Appendix D).

(7) Effect of better and deeper ballast on the cost of lining and surfacing. Committee reports progress.

Action Recommended

(1) Changes are covered in Appendix D.

(2) That Appendix A be accepted as a progress report.

(3) That Appendix B be accepted as a progress report.

(4) That Appendix C be accepted as a progress report.

(6) That the recommended revisions of the Manual appearing in Appendix D be approved.

Respectfully submitted,

The Committee on Ballast,

A. P. Crosley, *Chairman.*

Bulletin 362, December, 1933.

Appendix A

(2) SPECIFICATIONS FOR PREPARED GRAVEL BALLAST, INCLUDING BEST METHOD OF TESTING FOR HARDNESS, ABRASION, AND RESISTANCE TO WEATHERING

C. B. Stanton, Chairman, Sub-Committee; W. L. Foster, J. J. Gallagher, O. N. Lackey, W. A. Roderick, Stanton Walker, A. O. Wolff, A. H. Woerner.

The Committee is not able at this time to present information in addition to that given in its last year's report. This does not mean, in any sense, that the assignments to the Committee have been completed, but only that conditions during the past year have not been conducive to carrying forward the work.

In addition to its studies of a suitable grading for ballast, the Sub-Committee, during the past three years, has concentrated the largest proportion of its efforts on the development of information on methods of testing for hardness, abrasion, and resistance to weathering. In connection with these studies, 21 samples of gravel ballast were collected through the cooperation of railroads and of gravel producers, and subjected to abrasion, crushing, specific gravity, absorption, grading, weight, void, and soundness tests (see Vol. 31, 1930, page 761, and Vol. 33, 1932, page 350, of the Proceedings). Information concerning the service record in the track of 18 of these samples has been furnished to the Committee by representatives of the railroads (see Vol. 34, 1933, page 524, of the Proceedings).

These data have not shown sufficient correlation between the results of the field observations and the laboratory tests to indicate clearly what specification limitations should be placed on the various physical characteristics of gravel ballast, although some promising results were obtained. The Committee feels that the investigation should be continued along similar lines, with special attention being paid to the collection of samples representing a wider range in quality than those which have already been tested.

In addition to the tests on physical characteristics, the Committee has endeavored also to develop some information on the effect of grading and the proportion of crushed particles on the stability of gravel ballast in the track. So far this work has consisted only of some preliminary laboratory investigations of test methods. It cannot be said that the results obtained to date have been particularly valuable, but it is believed that this represents a problem which deserves further attention.

The Committee recommends, therefore, that these assignments be continued and it also asks the indulgence of the Association in making somewhat slow progress until economic conditions permit a more vigorous prosecution of the work.

Report is submitted as information.

Appendix B

(3) SPECIFICATIONS FOR STONE BALLAST, INCLUDING BEST METHOD OF TESTING RESISTANCE TO WEATHERING

J. M. Podmore, Chairman, Sub-Committee; C. J. Coon, H. F. Fifield, W. L. Foster, A. T. Goldbeck, W. W. Patchell, H. M. Righter, A. B. Shimer.

At the 1933 convention, your Committee submitted as information an alternate method for making an abrasion test on crushed stone as produced for ballast, known as the Modified Abrasion Test. Before recommending the adoption of this test it seems desirable to await developments from a series of tests which largely have been completed on still another modified form of abrasion test, making use of the so-called Los Angeles

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QUESTIONNAIRE IN REGARD TO CEMENTING VALUE OF BALLAST IN CONNECTION WITH PURCHASING PREPARED BALLAST

RAILROAD		Do your specifications contain a clause for "Cementing Value"?	If so, please give test methods contained in the specifications as to how this value is to be determined	If specifications show such a clause, what values do you specify for each character of material and what do laboratory tests show for said materials.	Do you actually make or require to be made the "Cementing Value" test?	Have you attempted to correlate laboratory cementing value with field behavior? If so, with what results?	By what laboratory are the test for "Cementing Value" made for your road?	How often do you require this test to be made for each source of supply?
In United States								
Alton	979	No						
Atchison, Topeka & Santa Fe	9,719	No			No			
Atlanta & West Point	556	No			No			
Atlanta, Birmingham & Coast	637	No			No			
Atlantic Coast Line	5,144	No			No			
Baltimore & Ohio	6,308	No			No			
Bessemer & Lake Erie	226	No			No			
Boston & Albany	402	No			No			
Boston & Maine	2,093	Yes	A. R. E. A. Specifications	A greater cementing value than 1 lb. should be rejected	In special cases			As needed in special cases
Central of Georgia	1,944	No			No			
Central of New Jersey	692	No			No			
Chesapeake & Ohio	3,145	No			No			
Chicago, Burlington & Quincy	9,260	No			No			
Chicago, Milwaukee, St. Paul & Pacific	10,894	No			No			
Chicago & Northwestern	8,442	No			No			
Chicago, Rock Island & Pacific	7,620	No			No			
Colorado & Southern	1,030	No			No			
Delaware, Lackawanna & Western	999	No			No			
Detroit & Toledo Shore Line	50	No			No			
Duluth, Missabe & Northern	564	No			No			
Elgin, Joliet & Eastern	447	No			No			
Erie	2,444	No			No			
Florida East Coast	868	No			No			
Georgia & Florida	465	No			No			
Great Northern	8,460	No			No			
Grand Trunk Western	1,023	Stone–Yes (Gravel–No	A. R. E. A. Specifications	A greater cementing value than 4 lb. per sq. in. should be rejected.	No		Quarry Co. Lab.	
Illinois Central	6,993	No			No			
Illinois Terminal	543	No			No			
Kansas City Southern	783	No			No			
Kansas City Terminal	27	No			No			
Lehigh & New England	217	No			No			
Louisville & Nashville	5,263	No			No			
Maine Central	1,121	No			No			
Michigan Central	1,858	No			No		Laboratories at State Univ. of Missouri, Oklahoma and Texas. The U.S. Bureau of Public Roads and Missouri St. Highway Com.	
Mississippi Central	150	No			No			
Missouri-Kansas-Texas	3,188	Yes	A. R. E. A. Specifications	For grade one stone ballast max 5 lb. per sq. in. Lab. test show in general, values in excess of this figure.	Yes	Yes. Hard to maintain ballast with high cementing value.		No Fixed Rule
Missouri-Kansas-Texas of Texas								
Missouri Pacific Lines	9,769	No			No			
Nashville, Chattanooga & St. Louis	1,203	No			No			
New York Central	11,446	No			No			
Nickel Plate	1,695	No			No			
Norfolk & Western	2,240	No			No			
Northern Pacific	6,702	No			No			
Pennsylvania	10,897	Yes	The test sample, 500 grammes (1.1 lb.) of pea size pieces of rock is revolved in the Deval abrasion cylinder with 3 cast iron balls 4.76 cm (1.875 inch) diameter and weighing approx. 0.43 kilogrammes (0.95 lb.) at the rate of 30 to 33 revolutions per min. and the stiff dough at room temperature resulting from about 500 grammes (17.64 oz.) of dust screened through a 100 mesh sieve, mixed with sufficient water thoroughly kneaded for five minutes, allowed to stand in an air tight container for 2 hrs., is moulded into cylindrical briquettes 2.54 cm (1 inch) diameter by 2.54 cm. (1 inch) in height under a pressure of 132 kgs. per sq. cm. (1877.5 lbs. per sq. in. after which they are dried for 20 hours in air at room temperature, 4 hours in a hot air bath at a temperature of 100°C (212°F.) then cooled for 20 minutes in a dessicator, and immediately tested in a compression testing machine for static crushing strength, the bearing heads being suspended by pivots to secure uniform distribution of load which is applied at 600 lbs. per minute approximately.	**TRAP ROCK** A maximum "Cementing value" in lb. per sq. in. of High Low Lime Grade Gr'de Stone Slag 75 250 450 600	Yes	No	P. R. R. Laboratory at Altoona, Pa.	Each new source and as needed.
Peoria & Pekin Union	159	No			No			
Pittsburg, Lisbon & Western	25	No			No			
Reading	1,575	No			No			
Richmond, Fredericksburg & Potomac	118	No			No			
St. Louis Southwestern	1,913	No			No			
St. Louis San Francisco	5,267	No			No			
Savannah & Atlanta	145	No			No			
Seaboard Air Line	4,389	No			No			
Southern Pacific	9,105	No			No			
Southern Pacific Lines—Tex. & La.	4,707	No			No			
Southern	8,021	Yes	A. R. E. A. Specifications	A greater cementing value than 4 lb for lime stone and 2 lb for granite should be rejected	Not Usually	No	R R Co Laboratory	As needed
Union Pacific	9,863	No			No			
Wabash	2,524	No			No			
Western Pacific	1,163	No			No			
Total in United States	197,480							
In Canada								
Canadian National	22,462	Yes	A. R. E. A. Specifications	A greater cementing value than 4 lb per sq. in. should be rejected.	Igneous Rock Yes Others–No	No	Can Inspec & Testing Lab. Ltd –Toronto	Each contract covering Igneous Rock.
Temiskaming & No. Ontario	552	No			No			
Total in U. S. and Canada	220,474							

Mileage of railroads reporting who **do not** use the "Cementing Value" 172,790
Mileage of railroads reporting who use the "Cementing Value" — 47,684

Rattler. Perhaps, also, a series of cooperative abrasion tests should be conducted to determine the proper test values to use in specifications for ballast. Your Committee recommends that tests for abrasion be given further study and, at a later date, that cooperative tests be undertaken to secure an idea of the proper test limits to be used in specifications for ballast.

Your Committee recommended that the section dealing with cementing value be removed from the specification for ballast. However, by instructions from the convention the subject of cementing value has been given further study. During the past year a questionnaire was sent out to railroads. Answers were received from 58 railroads, six of which advised that the cementing value test is used in the purchase of stone ballast. Of these six, five specify the A.R.E.A. method of making the test and one specifies a method which differs in a few details from the A.R.E.A. method. The answers to these questionnaires appear in the tabulation attached to this report.

The test requirement specified by the six railroads using the cementing value test varies all the way from 1 lb. to 450 lb. per sq. in. Tests made in the laboratory of the National Crushed Stone Association have shown that the cementing value of excellent trap rock may be as high as 670 lb. per sq. in. and of an excellent grade of limestone as high as 670 lb. per sq. in. Crushed quartz sand was shown to have a cementing value of 32 lb. per sq. in. when the test was conducted as required by the A.R.E.A. specification. A tabulation of test results for cementing value obtained in the National Crushed Stone Association laboratory is included herewith (See Table No. I).

Obviously, in view of the wide variation in the specification requirements of the six railroads using the cementing value test, coupled with the high results obtained with the A.R.E.A. test method, it is evident that an inconsistency exists, either in the test method itself, or in the requirements of the railroads specifying the A.R.E.A. method. Because of this inconsistency, it seems desirable to initiate a cooperative series of tests which will shed light on this entire matter of cementing value of rock for use as railroad ballast.

Such an investigation would seem to involve:

(1) A determination of the duplicability of the test method when made in different laboratories.
(2) A determination of the value of the test method for revealing the cementing value of rock under actual service conditions.

Do high cementing value laboratory test results consistently prove that the rock has highly cementitious properties in service? Do low results indicate a rock of excellent properties from the cementation standpoint as revealed by service results?

Perhaps through a cooperative series of tests some real facts will be obtained with regard to the test for cementing value. Your Committee is of the opinion that a cementing value requirement is unnecessary in connection with hard and tough rocks such as trap and granite, for very little dust is formed due to abrasion of these stones in actual service. On the other hand, soft grades of limestone which break down under the action of tamping tools and traffic and which are lacking in durability upon exposure to the weather, may form a large amount of dust. This dust when combined with water may produce a plastic mud which would stick together and interfere with drainage. It would seem that if the cementing value test has merit, its principal value must be in connection with these soft, non-resistant materials.

Your Committee is taking steps to initiate a cooperative series of cementing value tests with objectives as already indicated, with the hope of obtaining information of practical value for use in specifications for ballast.

Recommendation

That the above report be received as information.

Table I

TABULATION OF THE RESULTS OF TESTS ON RAILROAD BALLAST

For the Committee on Ballast, A.R.E.A. Made by the National Crushed Stone Association, January 1931

Lab. No.	Material	Spec. Gravity	Absorption %	Per cent Wear (Deval)	Coef. Hardness (Dorry)	Toughness (Page)	Crushing Strength lb./sq. in	Cementing Value lb./sq. in (crushing)	Sodium Sulphate Soundness % Loss 5 cycles	Wt. per Cu. Ft. Solid	Graduation (Round Openings) 3–2½	2½–1½	1½–¾	¾–¼	Pass. ¼
162	Cr. Limestone	2.66	0.5	3.1x				830	0	166	14	65	21		
163	Cr. Limestone	2.69	0.4	4.1x				830	0	168		63	37		
164	Crushed Trap	2.88	0.4	2.1x				590	0	180	2	83	15		
165	Cr. Limestone	2.70	0.1	3.1x				660	0	169	10	86	4		
166	Cr. Limestone	2.64	0.6	4.5x				870	0	165	48	52			
167	Cr. Limestone	2.66	1.2	4.3x				610	1	166		54	44	2	
169	Solid Limestone	2.71	0.3	3.1c	14.7	9	31,200	870	0	169					
170	Solid Limestone	2.64	0.7	4.0c	13.1	7	21,500	1100	1	165					
171	Cr. Limestone	2.74	0.7	2.8x				590	0	171	3	62	33	2	
172	Solid Limestone	2.68	1.5	3.2c	14.3	9	31,800	530	3	167					
184	Solid Limestone	2.68	0.2	4.6c	13.0	5	16,400	990	1	168					
248	Cr. Limestone	2.69	0.3					710	0	168		16	48	33	3
	Crushed Quartz Sand (Tested for cementing value only)							32							

x Commercially Crushed Fragments
c Hand broken Fragments

	Submitted by	Identification No.	Source of Supply
162	Louisville & Nashville		Upton, Ky.
163	Illinois Central	2	
164	N. Y. N. H. & H.		Fort Springs, West Va.
165	C. & O.		
166	Illinois Central	1	
167	Illinois Central	3	Kankakee, Ill.
169	Illinois Central	2	Cedar Bluff, Ill.
170	Illinois Central	1	Stephensburg, Ky.
171	Toronto, Hamilton & Buffalo		Dundas, Ont.
172	Illinois Central	3	Kankakee, Ill.
184	Illinois Central	4	Stolle quarry
248	St. Louis S. W.		Hely's quarry, Cape Girardeau, Mo.

Appendix C

(4) COMPARATIVE COST OF MAINTAINING TRACK ON VARIOUS KINDS OF BALLAST

J. B. Wilson, Chairman, Sub-Committee; J. J. Gallagher, C. G. Grove, Daniel Hubbard, H. M. Long, C. S. Wicker.

During the past year your Committee has endeavored to obtain information on this subject, with very little success. Ballast on one of the two sections reported on for the past few years has been changed; therefore these sections have been eliminated from further comparative study.

The following is a brief outline of the information desirable for a report on this subject:

(A) Track—

1. Weight of rail
2. Joint
3. Per cent of and size of tie plate
4. Size and spacing of ties
5. Kind of ties and per cent treated

(B) Ballast—

1. Kind
2. Specifications
3. Depth and material of sub-ballast
4. Depth of top ballast
5. Ballast section
6. Cost per yard delivered to railroad

(C) Roadbed—

1. Character of subgrade
2. Alinement

(D) Traffic—

1. Number per day and average speed of passenger trains
2. Number per day and average speed of freight trains
3. Type of locomotive
4. Tonnage

(E) Labor—

1. Size and makeup of gangs
2. Man hours separated between foremen, laborers, etc.

(F) Maintenance Methods—

1. Cycle of maintenance
2. Kind and number of mechanical appliances used

(G) Costs—

1. Detail costs per mile of track reported on.

Conclusion

The Committee believes that no accurate comparison can be obtained from data such as is being kept by railroads. Only by test sections carefully watched by this Committee for a period of several years can definite conclusive results be obtained.

Appendix D

(6) DETERMINE PROPER DEPTH AND KIND OF SUB-BALLAST

A. D. Kennedy, Chairman, Sub-Committee; C. G. Grove, O. N. Lackey, J. M. Podmore, C. P. Richardson, J. W. Stone, A. H. Woerner.

This question was first assigned in 1931. It involves the old question of "Proper Depth of Ballast" which has been before the Association since 1902. To familiarize itself with this subject, the Committee made a survey of the Proceedings of the Association, and offers for convenience, the following historical review:

The first mention of the question of "Proper Depth of Ballast" is in Vol. 3, page 130. The Committee made this recommendation: "For ballast materials that will stand at a one-to-one slope, such as crushed stone, not less than the distance between the ties; for other materials that will stand at a lesser slope requires a greater depth."

On page 104, Vol. 7, Mr. Johnson states a formula for proper depth of gravel and stone ballast. This formula is largely based on the findings of Director Schubert of the German Railways from a lecture delivered in Berlin in 1899. A translation is given on page 105.

In Vol. 12, Part 1, page 341, are given some of the conditions on which depend the "Proper Depth of Ballast," and in Appendix A, page 345, is given the depth of various kinds of ballast used at that time by representative railroads.

On pages 95 to 265 inclusive of Vol. 13 is given interesting information regarding this subject, particularly regarding experiments and tests conducted by the Pennsylvania Railroad. These experiments and tests were made with new or clean ballast and not under regular traffic conditions.

With the data made available by these tests, the Ballast Committee of that year concludes as follows: "Your Committee finds that with the ties (7″ × 9″ × 8½′) spaced approximately 24 in. to 25.5 in. center to center, a depth of 24 in. of stone ballast is necessary to produce uniform pressure on the subgrade, and a combination of a lower layer of gravel or cinder ballast (18 in. to 14 in.) and an upper layer of stone ballast (6 in. to 10 in.) approximately 24 in. in depth in the aggregate with the same spacing of ties will produce nearly the same results."

The question of "The proper depth of ballast of various kinds to insure uniform distribution of loads on the roadway" is summarized in the Committee's report in Vol. 16, pages 1011 to 1015. In this summary, reference is made to a proposed test to be conducted under regular traffic and under the supervision of the Committee. In the discussion on the report of this Committee, skepticism was expressed relative to any recommendation which makes 24 in. the proper depth of ballast, the inference being that sufficient information on which to base or support a recommendation was not available.

In Vol. 17, the same question was considered under the caption of "The economical and efficient depth of ballast." The Committee recommended in their report the carrying out of the special test suggested in previous reports. (A complete outline of this test is given on page 1015, Vol. 16.) In Vol. 18, the Committee submitted, for information, that the proposed test would be installed in 1918. However, subsequent reports do not indicate this test was ever carried out.

Under discussions on report of the Committee on Stresses in Railroad Track on page 1476, Vol. 18, it was stated that laboratory tests showed that the pressures begin to become rather uniform when a depth of 18 in. or 20 in. under the tie is reached.

On page 454, Vol. 18, attention is directed to the fact that the recommended depth of ballast of 24 in. was made on the assumption of 2640 ties per mile, and that at this

time railroads were increasing the number of ties per mile, which would affect the recommended depth of ballast.

At the 1917 convention, the proper depth of ballast was adopted, viz., "The depth of ballast under the tie on roadbed materials, such as clay, loam, etc., subject to deformation by the application of live loads, would seem to be not less than the spacing of center to center of ties."

In Vol. 22, page 80, Appendix A, the recommendations of the preceding committees on proper depth of ballast is carried up-to-date and summarized into six paragraphs. This summary was approved and now appears in the 1929 Manual on page 102, and for convenience, these paragraphs are quoted, as follows:

"Proper Depth of Ballast

"(1) On a roadbed material such as clay, loam, etc., subject to deformation by the application of live load, the proper depth of ballast under the tie to produce approximately uniform pressure on the roadbed, should be not less than the spacing center to center of the ties. For Class A Track, see Ballast Sections.

"(2) On material that approximates the character of good sub-ballast (which will not be deformed by the application of live load), the minimum depth of ballast under the bottom of the tie should be twelve (12) in.

"(3) These depths are required, under the conditions named, to support the track structure; to provide good initial drainage; to reduce upheaval by frost; to serve as a cushion for the track.

"(4) A combination of a good sub-ballast 18 to 14 in. and top-ballast 6 to 10 in., making a total of approximately 24 in. under the tie in the aggregate, will produce nearly the same result as though the superior material was used for the full depth.

"(5) Until sufficient tests are made under normal traffic conditions, the proper depth of ballast under the tie must rest on opinion, based on experience and supported by such tests as are available, notably the test made by Director Schubert of the German Railways and the 'Altoona Test' made by the Pennsylvania Railroad.

"(6) Proper drainage of the subgrade is essential to success with any kind of ballast."

In considering this new subject of "Proper depth" and kind of sub-ballast, a distinction should be made between new construction and old established lines.

In new construction, such materials as screenings, pit run gravel, cinders, slag, sand, etc., are used as sub-ballast with satisfactory results, but, in general, availability and cost determine the kind to use. It is not considered good practice to place a ballast section of materials such as crushed stone, broken slag or prepared gravel on new subgrade, without sub-ballast, since the subgrade materials (consideration to be given to the materials in the subgrade) will, under traffic, become mixed with the ballast.

After years of service, the sub-ballast of an original ballast section loses its identity as such. It becomes so mixed with the subgrade that a distinction is impossible and with repeated replenishments of the top-ballast section, several feet of top-ballast material have been found under the ties. Therefore, the Committee concludes the question of sub-ballast does not apply to old, established roadbeds but is restricted to new construction.

The Committee is of the opinion that within certain limits materials of smaller aggregates are to be preferred for sub-ballast, since such materials have a greater tendency to prevent the subgrade working up into the ballast. The thickness or proper depth of sub-ballast to use depends upon sundry conditions and variables. Experienced engineers, after acquainting themselves with all the conditions to be encountered, should be able to approximate the proper depth to use.

Some railroads, in their reply to the questionnaire (details of which are given in Appendix E of the 1932 report), indicated that due to the increased weight of power,

equipment and changes in general conditions, the 24-in. ballast section, as shown in the 1929 Manual, is not adequate for their present-day needs. For this reason and for lack of definite information regarding the many existing and ever-changing conditions particular to each location, your Committee feels this Association cannot defend, except by opinion, a ballast section of any specific dimensions. However, there is information contained in the Proceedings of the Association, reference to which is given in this report, which, if intelligently interpreted, would be a guide in determining both the proper depth of ballast and sub-ballast to use in any particular location.

The Committee feels that paragraph five (5) under the caption "Proper Depth of Ballast," as it now appears in the Manual, conflicts with the preceding paragraphs. We further find the minimum ballast sections of 12 in. and 24 in., approved by the Association, are not supported by data. Therefore, your Committee recommends the following be substituted for the six paragraphs, under the caption "Proper Depth of Ballast."

(1) There is a relationship between several conditions, viz., rail section, ties, tie spacing, kind of ballast, speed, wheel loads, drainage, subsoil, kind of traffic, etc., and the depth of ballast. Depth of ballast should exceed the minimum required to uniformly distribute superimposed loads to the subgrade without causing its deformation. Available data does not support a definite specification with reference to required depth for general application under all conditions.

(2) In new construction a combination of good sub-ballast and top-ballast does, with few exceptions, produce better results than a superior material used for the full depth. The ratio of the one to the other and the total depth in the aggregate should be determined with due consideration given to local conditions, as outlined in Paragraph 1.

Note.—In the absence of more specific data, the tests made by Director Schubert of the German Railways (Vol. 7, pages 104 to 127) and by the Pennsylvania Railroad (Vol. 13, pages 95 to 265), although not conducted under regular traffic conditions, are of great value as a guide in determining the depth of ballast required for any given section of track.

Reference is also made to Vol. 12, Part 1. On page 341 are given some of the conditions on which depend the proper depth of ballast and in Appendix A, page 345, is given the depth of ballast used at that time by representative railroads.

It would appear from the present captions that the ballast sections shown on pages 103 and 104 of the Manual are the Association's recommended sections and do not admit of any modifications. The Committee recommends that these captions be changed to read:

Typical Stone Ballast Section with Particular Reference to Sub and Top-Ballast (See under heading "Proper Depth of Ballast")

Similarly, the caption on page 105 to read:

Typical Gravel Ballast Section with Particular Reference to Sub and Top-Ballast (See under heading "Proper Depth of Ballast")

On page 106 of the 1929 Manual are shown recommended ballast sections for Class "B" and "C" tracks which were adopted in 1907. The Committee recognizes that Class "B" and "C" tracks, under certain conditions, require ballast section equivalent to Class "A" tracks, and for this reason recommends striking out reference to Track "B" and "C" on page 106 and to change the caption on top of page to read as follows: "The sections shown below are suggested for less important main lines and for branch lines and other tracks of sundry importance (see under heading "Proper Depth of Ballast").

Action Recommended

That changes in 1929 Manual be approved as given above.

REPORT OF COMMITTEE XVI—ECONOMICS OF RAILWAY LOCATION

F. R. Layng, *Chairman;*
S. E. Armstrong,
J. L. Campbell,
H. H. Edgerton,
R. P. Forsberg,
A. W. Galbreath,
W. L. R. Haines,
E. A. Humphreys,
E. E. Kimball,
E. E. King,
Fred Lavis,
Wm. Michel,
G. H. N. Monkman,
H. M. Shepard,
H. C. Searls, *Vice-Chairman;*
R. S. Stephens,
H. M. Stout,
J. E. Teal,
H. M. Tremaine,
W. D. Wiggins,
J. C. Wrenshall,
Committee.

To the American Railway Engineering Association:

DEFINITION OF "RISE-AND-FALL"

The term "Rise-and-Fall" has been defined or used by various writers on the economic theory of railway location, and is frequently used by many engineers with or without explanation or definition. The following definitions have been abstracted from publications generally referred to in studies of railway location:

Wellington—"Economic Theory of Railway Location," Par. 450.

"A foot of 'Rise-and-Fall' means a foot of ascent with its corresponding foot of descent."

Raymond—"Elements of Railroad Engineering," page 239.

" 'Rise-and-Fall' is considered to be the rise in feet on an ascending grade and the corresponding feet of fall on some descending grade."

Webb—"Economics of Railroad Construction," page 287, Par. 184.

"In the simplest case a 'Rise-and-Fall' of so many feet means a rise from the starting point to a summit and a return to the same level."

Willard Beahan—"Field Practice of Railway Location," page 175.

"It follows that the total 'Rise-and-Fall' of a line will be the difference in elevation of the extremities of the line plus the unnecessary summits and unnecessary drops. If ground is found to support a grade line all the way, the 'Rise-and-Fall' is merely the difference in elevations of the terminals of the lines."

Williams—"Design of Railway Location," page 219 and 255.

"The second class of grades, or those less than the ruling grade, are termed 'Rise-and-Fall.'

" 'Rise and Fall' may be defined as the rise from a datum elevation to a summit with the corresponding descent to the same datum elevation."

1929 A.R.E.A. Manual—Page 1258—"(3′) 'Rise-and-Fall.' "

" 'Rise-and-Fall' affect line resistance and may affect time, but to what measurable extent is indeterminate.

"The amount of 'Rise-and-Fall' of each alternate location in vertical feet should generally be determined and considered as an aid to judgment in forming final decision as between locations, but may be neglected entirely in comparing alternate locations where there is small difference in 'Rise-and-Fall'."

A study of these definitions reveals that different values may be obtained for the amount of "Rise-and-Fall". Where the termini of the section of road for which "Rise-and-Fall" is to be determined are at the same elevation, no confusion arises in computing it, the answer being the summation of vertical rises in the profile, as it is evident that

for each foot of rise there will be a corresponding foot of fall. Where there is a difference of elevation between the termini of the section of line under consideration, confusion arises in the determination of the number of feet of "Rise-and-Fall", as it is evident that there will be a difference between the sum of the vertical rises and the sum of the vertical falls by the difference in elevation between the termini.

As traffic in practically all cases moves in both directions over the same grades, it seems sufficient for all practical purposes to compute "Rise-and-Fall" for a round trip over the section under consideration. Under this method the total rises and total falls become equal, and the "Rise-and-Fall" for the line is given by one half the sum of the vertical ascents for a round trip. While the amount of "Rise-and-Fall" obtained from the computation of same for a round trip does not exactly fit the theory under which the effect of "Rise-and-Fall" on operating expenses is treated, no great error is incurred, and as the effect of "Rise-and-Fall" on operating costs is of minor importance the errors inherent in this method will be of little consequence.

In view of the above the Committee therefore presents the following definition of "Rise-and-Fall": "Rise-and-Fall" is the sum of vertical ascents in rising from a starting point or level to a summit and returning to same point or level, inclusive of all grades on the profile between any two points or termini. It is mathematically expressed by the formula

$$\frac{\textit{Sum of ascents in one direction} + \textit{Sum of descents in same direction}}{2}$$

EFFECT OF "RISE-AND-FALL"

While the mathematical definition of "Rise-and-Fall" given above may be used to obtain a mental comparison of two profiles, the figures thus obtained cannot be used in a concrete way for estimating the relative operating expenses of the two profiles. "Rise-and-Fall" to be useful for this purpose must be divided into the following classes, each of which has a different effect on operating expenses:

Class "A"—"Rise-and-Fall" in minor gradients and for small undulations, not sufficient to make it necessary to vary the power of the engine, but merely causing a momentary, gradual and unobjectionable fluctuation in speed. Not requiring shutting off steam, nor change in the natural velocity, nor use of brake or sand.

Class "B"—"Rise-and-Fall" similar to Class "A", in its effect on speed, provided steam be shut off in descending, but not requiring the use of brakes in descending, nor seriously taxing the power of the engine on the ascent. Requiring the shutting off steam at the head of the grade but not use of brakes or sand.

Class "C"—"Rise-and-Fall" requiring the use of brakes in descending, in addition to shutting off steam, in order to avoid excessive velocities and consequently in almost all cases, more or less use of sand in ascending. Requiring use of both brakes and sand.

Separation of "Rise-and-Fall" as among the three classes given above is accomplished by first fixing the maximum permissible speed for the class of service under consideration, and second, by the construction of a virtual profile by the usual method, on which the grades of each class can be marked in colors.

Preparation of the virtual profile and determination of "Rise-and-Fall" according to the above classifications requires a study of the actual profile and alignment and other features of the line, including locations where for any reason the speed of trains must be restricted, and of the characteristics of the locomotive used.

In any computation of costs Class "A" can be omitted, no expense can be directly traced to it in any single item. This leaves Class "B" and Class "C" to be considered in the determination of operating cost. For these classes no leading item of operating expenses is largely affected and very many are not affected at all.

"Rise-and-Fall" is most conveniently estimated in terms of vertical feet. The use of the number of vertical feet without any qualifications as an aid to judge between two locations may mean practically nothing.

Fig. 1 and 2 show two profiles which have the same "Rise-and-Fall". However, the grade is much heavier in one case than in the other, and to assume equality in cost of operation over them because of the fact that "Rise-and-Fall" is the same in each case is erroneous.

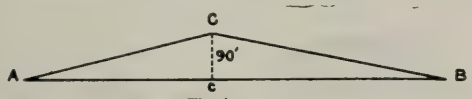


Fig. 1.

$$\text{Rise and Fall} = 90 = Cc = \frac{\text{Rise in } AC + \text{Fall in } BC}{2}$$

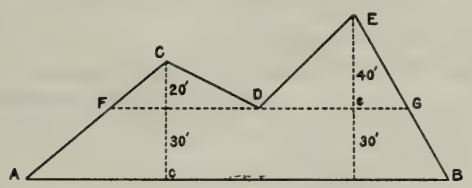


Fig. 2.

$$\text{Rise and Fall} = \frac{\text{Rise } AC + \text{Fall } CD + \text{Rise } DE + \text{Fall } EB}{2} = \frac{50+20+40+70}{2} = 90$$

Fig. 3 further illustrates this. The two lines have the same "Rise-and-Fall", the ruling grade shown by solid lines is 1 per cent and the ruling grade shown by dotted lines is 1.5 per cent. A comparison of the operating cost over these profiles would have to be made on some other basis than "Rise-and-Fall", and it is possible the heavier ruling grade might be selected on account of various other factors.

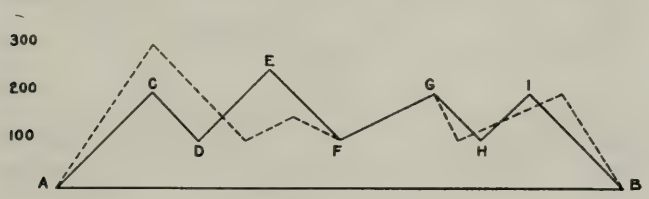


Fig. 3.

In Fig. 3 are shown 2 profiles from A to B, one by Solid Lines, one by Dotted Lines. By adding together the rises and descents and dividing the result by 2 it will be found that Rise and Fall is the same on both profiles.
The maximum or operating grade on Dotted Line is 50% in excess of maximum grade on Solid Line, or

$$\text{R.\& F. (Solid Line)} = \frac{AC + CD + DE + EF + FG + GH + HI + IB}{2} = 550$$

ITEMS OF OPERATING COST AFFECTED BY "RISE-AND-FALL"

The main effect of "Rise-and-Fall" is in fuel and time. At the present time the Committee is not prepared to offer any method of determination of the effect of "Rise-and-Fall" on these items of operating expenses or to state whether or not other items of operating expenses are affected by same, and to what extent.

Conclusion

It is recommended that the following definition of "Rise-and-Fall" be adopted: "Rise-and-Fall" is the sum of vertical ascents in rising from a starting point or level to a summit and returning to same point or level, inclusive of all grades on the profile between any two points or termini. It is mathematically expressed by the formula—

$$\frac{\textit{Sum of ascents in one direction} + \textit{Sum of descents in same direction}}{2}$$

Respectfully submitted,

THE COMMITTEE ON ECONOMICS OF RAILWAY LOCATION,

F. R. LAYNG, *Chairman.*

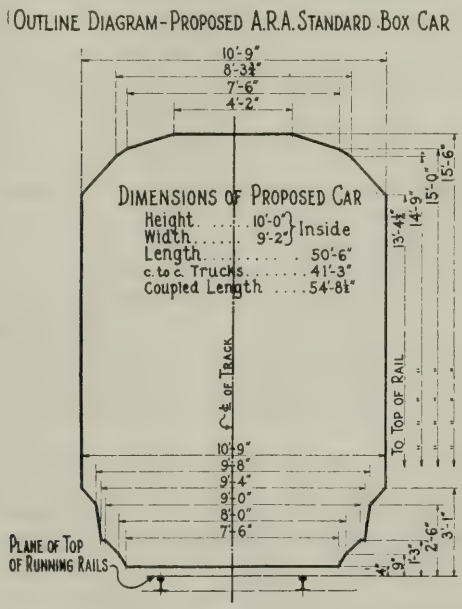
REPORT OF SPECIAL COMMITTEE ON CLEARANCES

A. R. Wilson, Iron and Steel Structures, *Chairman;*
J. E. Armstrong, Assistant Chief Engineer, Canadian Pacific Railway (representing Canadian Practice);
H. Austill, Wooden Bridges and Trestles;
R. C. Bardwell, Water Service and Sanitation;
E. H. Barnhart, Rules and Organization;
J. G. Brennan, Grade Crossings;
G. S. Fanning, Roadway;
P. M. Gault, Signals and Interlocking;
C. J. Geyer, Track;
W. S. H. Hamilton, Electrical Section;
M. J. J. Harrison, Yards and Terminals;
Meyer Hirschthal, Masonry;
J. M. Metcalf, Shops and Locomotive Terminals;
G. A. Rodman, Buildings,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully submits the following as its report:

Outline of Proposed A.R.A. Box Car (Fig. 6).



This diagram continues the series that this Committee will present from time to time supplementing Fig. 1, 2, 3, 4 and 5, which have been adopted by the Association and appear in the revisions and additions to the Manual, as published in Bulletins 337, July 1931, and 347, July, 1932.

Action Recommended

That the outline of proposed A.R.A. box car, Fig. 6, be approved and printed in the Manual.

Respectfully submitted,

The Special Committee on Clearances,

A. R. Wilson, *Chairman.*

Bulletin 363, January, 1934.

REPORT OF COMMITTEE XXV—RIVERS AND HARBORS

W. C. Swartout, *Chairman;* E. H. Roth, *Vice-Chairman;* A. P. Wenzell, *Vice-Chairman;*
W. J. Backes,
G. J. Bell,
L. R. Boettcher,
W. G. Brown,
D. J. Brumley,
W. H. Courtenay,
A. F. Crowder,
L. G. Curtis,
Benjamin Elkind,
G. S. Fanning,
W. D. Faucette,
R. A. Feldes,
Robert H. Ford,
R. E. Fristoe,
I. W. Geer,
G. F. Hand,
W. E. Hawley,
J. R. Hickox,
F. G. Jonah,
C. S. Kirkpatrick,
G. A. Knapp,
C. F. Loweth,
P. J. McCarthy,
F. E. Morrow,
G. J. Ray,
H. F. Sharpley,
C. U. Smith,
G. R. Westcott,
J. E. Willoughby,
R. C. Young,

Committee.

To the American Railway Engineering Association:

Your Committee on Rivers and Harbors respectfully presents its report on the following subjects:

(1) Revision of Manual (Appendix A).

(2) Definitions of Terms (Appendix B). These definitions are tentative and the Committee will welcome suggestions.

(4) Specifications for the Construction of the Several Types of River Bank Protection in Common Use (Appendix C).

(5) Types of Bulkheads, Jetties and Sea Walls, Giving Cross-Section of Each and Stating the Purpose which they Serve, Including Comparisons of First Cost, Service Life and Maintenance Cost of the Various Types (Appendix D).

(6) Types of Fender Systems for Protecting Wharves and Recommend Suitable Uses for Each, Including Comparisons of First Cost, Service Life and Maintenance Cost of the Various Types (Appendix E).

(7) Warehouse Piers, Coal and Ore Piers, Car Float Piers and Others, with Recommendation as to the Type Suitable for Use Under Various Conditions, Including Comparisons of First Cost, Service Life and Maintenance Cost of the Various Types (Appendix F).

(10) Economic Principles Involved in Clearances over Navigable Waterways (Appendix G).

(11) Cost to Railways for Construction, Maintenance and Operation of Bridges over Navigable Waterways: (a) In the Natural Condition of Streams; (b) Additional Costs brought about on account of the Enlargement of the Capacity of the Streams over and above their Natural Conditions (Appendix H).

It is the recommendation of your Committee that all the above reports be accepted as information and the subjects continued.

Progress is reported on the following subjects:

(3) Suitable Types of Construction for Levees, Dikes and Mattresses for Use under Varying Service Conditions, giving Consideration to Stream Alinement, Subsurface, Soil or other Local Conditions.

(8) Size and Depth of Slips Required for Economical Operation of the Various Types of Wharves and Traffic Conditions, including Comparisons of First Cost, Service Life and Maintenance Cost of the Various Types.

(9) Harbor Structures.

Respectfully submitted,

The Committee on Rivers and Harbors,

W. C. Swartout, *Chairman.*

Bulletin 363, January, 1934.

Appendix A

(1) REVISION OF MANUAL

E. H. Roth, Chairman, Sub-Committee; Robert H. Ford, W. C. Swartout, A. P. Wenzell.

Sub-Committee No. 1—Revision of Manual, after due consideration of the other Sub-Committee reports, has no recommendation to make on Manual revision for the current year.

The Committee is reviewing the Manual and Supplements thereto studying material therein which has heretofore been submitted by other committees, but which would now properly come within the scope of this Committee.

If any revisions are thought necessary on completion of this study, suitable recommendations will be submitted at a future date.

Appendix B

(2) DEFINITIONS OF TERMS (TENTATIVE)

W. C. Swartout, Chairman, Sub-Committee; W. J. Backes, L. R. Boettcher, D. J. Brumley, W. E. Hawley, G. A. Knapp, F. E. Morrow.

Barge.—A low, light draft cargo boat usually flat decked and flat bottomed, generally used for conveyance of freight on inland and coastal waterways.
— Self-Propelled.—A barge which may proceed under its own power.
Boat.—Any water craft with a hollow hull.
Bulkhead.—(1) A partition in a boat.
(2) A structure built to hold filling along a water front.
Canal.—An artificial waterway.
— Boat.—A boat built for conveyance of cargo on navigable canals.
Clearance, Horizontal or Lateral.—(1) The clear width between channel lines available for operation of boats.
(2) The clear width between bridge abutments and/or piers or the clear width between other structures in or adjacent to a channel.
— Vertical.—The clear height from a surface of the water to the lowest point of a structure over a waterway.
Craft.—Any floating transportation unit.
Draft (of Boats).—The depth to which a craft sinks in the water.
Dam.—A barrier across a waterway to impound water.
Economic Justification.—The requirement that the earnings from a project under competent and careful management shall be sufficient to pay annually, after a predetermined development period, the interest on the total amount invested including development costs, depreciation on the entire plant, an amount equal to all taxes legally assessable, and all other costs or charges accrued necessary to maintain the project in proper condition for efficient operation.
Lock.—A structure in a waterway for the purpose of raising or lowering water craft to predetermined elevations by opening and closing control gates.
Navigable.—Capable of being navigated by water craft.
— Waterways, Natural.—A natural stream or channel of sufficient width and depth for practical navigation by water craft without dredging or construction of controlling works.
— — Artificial.—A stream, channel or canal made navigable by dredging and/or construction of controlling works.
Navigate.—To sail over, traverse by water craft.
Navigation.—The art of navigating.
Passing Basin.—A widened portion of a river or canal to permit water craft to pass one another.
Pier, Private.—A pier or dock owned or restricted to use by one or more individuals or corporations.

— Public.—A pier or dock operated for the benefit and use of the public.
Piles, Anchor.—Piles driven on the land side of a bulkhead or pier to which the bulkhead or pier is anchored or tied by rods, cables, chains or other devices.
— Cluster or Fender.—Two or more piles driven and lashed together at the top for the purpose of controlling the position of water craft at bridges and piers.
Right-of-Way.—An easement or right to use, for a specific purpose, land of another and founded on grant by writing or prescription.
River Boat.—Any water craft primarily designed to operate upon inland streams and/or canals, or any similar water craft principally so used.
Ship (Noun).—A vessel primarily designed for deep water navigation.
Tariff, Freight.—A published list or schedule of charges prescribed by lawful authority and applied under conditions stated therein for specified services rendered in the transportation of freight.
Tolls, Waterway.—A charge or compensation levied by law for the right or privilege granted in the use of specified inland and/or coastal waterways.
Tow, Pull (Noun).—Water craft being navigated by power other than its or their own, the tow line between the power unit and the tow being in tension.
— Push (Noun).—Water craft being navigated by power other than its or their own, the power unit operating behind the tow.
Tug (Noun).—A powered non-cargo carrying boat used to tow or handle other water craft.
Vessel.—A boat designed to navigate the high seas or lakes.

Appendix C

(4) SPECIFICATIONS FOR THE CONSTRUCTION OF THE SEVERAL TYPES OF RIVER BANK PROTECTION IN COMMON USE

P. J. McCarthy, Chairman, Sub-Committee; G. J. Bell, L. R. Boettcher, A. F. Crowder.

DETAILED SPECIFICATIONS

1. **Location.**—

2. **Work to be Done.**—The work to be done under these specifications consists of furnishing all material, labor, plant equipment, machinery and tools, and therewith constructing, erecting and installing about (...) linear feet of pile diversion dike and a (...) foot bankhead and revetment, as hereinafter specifically set forth.

(b) The right is reserved to vary the length of the diversion dike by either increasing or decreasing the length herein proposed, and the cost to the Railway Company shall be for a completed dike at the price bid by the Contractor per linear foot, plus a lump sum to cover the (...) foot bankhead and revetment.

(c) It is understood that the contractor has personally visited the location of the work and has familiarized himself with the difficulties to be encountered in the execution of the contract, including depth of water, lengths of piles required, availability of material and uncertainties of weather and other contingencies.

3. **Drawings.**—

4. **Mattress.**—(a) The mattress shall be fabricated from live, bar growth willow brush cut not more than two weeks prior to use, having a butt diameter between one (1) and two and one-half (2½) inches, and the length exceeding ten (10) feet. The limb growth shall be stripped from the lower half of the stem. The use of a small percentage of young cottonwood mixed with the willows is permissible.

(b) Temporary anchor piles, to be removed after they have served their purpose, shall be driven near the edge of the mattress so spaced as to hold it safely in position during construction and to guide it to position on the bottom of the river when being ballasted.

(c) In starting the mattress a header shall be formed across the head of the mattress with a brush bundle fifteen (15) inches in diameter, wrapped with four wraps of No. 12 galvanized wire at intervals of three (3) feet. Butts of willows for weaving shall be thrust diagonally through the header roll, and securely fastened with No. 9 galvanized wire. The willows shall be plaited over and under in basket fashion to

produce a tightly woven brush surface free from open interstices, *the willow tops lying underneath.* Before weaving the mattress, snags, logs or other obstructions, which might prevent it from lying evenly in contact with the river bed, shall be removed.

(d) At the head of the dike the bank is to be sloped three (3) horizontal to one (1) vertical. The mattress is to be a continuation of the mattress extending from the bank-head and carried downstream on line with the dike. It shall be woven around the piles extending fifty (50) feet outside the outside or stream row of piling, through the dike proper, and twenty (20) feet inside the inside or land row of piling, making ninety (90) feet in width from edge to edge of mattress. When the dike is complete the mattress shall extend fifty (50) feet below the last pile bent at the downstream end.

(e) The mattress shall be woven to a full twelve (12) inch thickness, of close weave and tight stitch, and shall have a selvedge border which shall be formed by plaiting the willow tops into the weave at the edge of the mattress so there will be no loose ends. The mattress shall be of continuous weave throughout, unless conditions require that it be woven in sections, in which case each section must lap at least thirty (30) feet over the preceding section. Construction in sections shall not be allowed without the approval and sanction of the Engineer. No additional payment will be allowed for overlapping.

(f) The mattress shall be reinforced with continuous lines of three-eights (3/8) inch strand cable, composed of seven (7) No. 11 wires, laid in pairs on top and underneath, and spaced sixteen (16) feet apart longitudinally and transversely. At each intersection the four cables shall be tightly drawn through the mattress with a toggle hook made for that purpose and fastened with a four part "U" clip. Free ends of strands shall be clipped together in pairs at the selvedge with "U" clips.

(g) If the Engineer so directs, a line of poles shall be lashed across the extreme downstream end of the mattress, and a parallel row 16 feet back from this end with longitudinal poles 16 feet centers reaching between them forming cribs 16 feet square. This is to keep the stone from slipping off the end of the mattress if it would be likely to take a steep slope owing to under-scouring at the end. The poles across the end shall be two (2) high, but the others one (1) high. The poles shall be straight and of good timber, not less than six (6) inches in diameter at the butt and three (3) inches in diameter at the top. The poles shall lap at end two (2) feet or more and be fastened securely to the mattress with three-eighths (3/8) inch galvanized strand.

(h) Stone shall be evenly distributed upon the mattress for sinking in such manner as to cause it to establish contact with the river bed throughout, in the quantity of not less than one (1) ton per square (100 square feet) of mattress.

(i) If the mattress be injured by floods, driftwood, or otherwise during construction or sinking, the contractor shall repair or replace the damaged or destroyed portions without charge as directed by the Engineer.

5. **Stone for Ballast.**—All stone for ballasting the mattress shall be hard, sound, clean material that will withstand the action of the elements, and the weight of any stone shall not be less than twenty-five (25) lb. nor more than one hundred twenty-five (125) lb.

6. **Dike Piling.**—All piling must be of untreated cypress cut above the ground swell from sound live timber not more than six months before delivery. They shall be sawed square across the butt, bark peeled and the limb growth shall be cut close and smooth. They shall have a butt diameter between twelve (12) and fifteen (15) inches, a tip diameter not less than seven (7) inches and shall taper uniformly between butt and tip. They must be free from rot, loose or decayed knots, wind-shakes or other defects which would render them unsuitable for the use intended. They must be straight, in no case curving more than one fourth (1/4) inch per foot of length with maximum deflection near the mid-length. Curvature in more than one direction or short bends will be sufficient cause for rejection. Each pile driven shall be sharpened to a point three (3) inches in diameter (or square) and the length of scarf shall be about one and one-half (1½) times the diameter of the pile before pointing.

7. **Dike Construction.**—(a) The piles shall be driven to a least penetration of twenty (20) feet, and shall be forty (40) to sixty (60) feet in length. The tops of the piles, when driven, shall be at same elevation, as the top of the bank, which has an average elevation of about (...) feet above zero of the gage, unless the Engineer shall deem it necessary or expedient to vary the height to suit conditions; but no change in the specified height of the dike shall be made without the written consent of the Engineer. Piles shall be driven, as nearly plumb as it is possible to drive them from a river driver

in deep water, in bents of three piles to the bent, ten (10) feet apart, and the spacing of the bents shall average not more than ten feet, center to center, for the length of the dike. If necessary to secure adequate penetration of the piles without injury to the pile heads, a water jet shall be used in conjunction with the hammer. All piles shall be cut off square at the elevation of the determined height of the dike and the top row of bracing shall be placed so that the top edge of the braces are not more than two (2) inches below the top of the piles.

(b) After driving, the piles shall be braced transversely and longitudinally as shown on the plans. The transverse bracing shall consist of a double line of four (4) by eight (8) inch timbers twenty-two (22) feet long near the top of the pile, a similar set of bracing as nearly twelve feet below the top bracing as stage of river will permit and two diagonal braces four (4) by eight (8) inch by twenty-six (26) feet long, extending from the lower side of the top bracing to the upper side of the bottom bracing on opposite sides of the piles. The ends of the horizontal transverse bracing shall be placed and the corners of the diagonal transverse bracing shall be sawed off flush with the outer face of the stream row of piling.

(c) The longitudinal bracing shall consist of a double line of bracing near the top of the piles, and a double line of bracing below the top on the two outside rows of piling and a single line of bracing near the top of the piles and a single line of bracing below the top on the middle line of piles. The spacing between the top and bottom lines of bracing will be governed by the spacing of the transverse bracing, but it is desired that the average spacing between top and bottom bracing shall be as near twelve (12) feet as stage of water will permit. All longitudinal brace timbers shall be four (4) by eight (8) inch, all twenty-two (22) feet long. The lap of the brace timbers at the top of the piles in each row shall alternate with the lap of the timbers below. All brace timbers shall be long leaf pine, square edged and sound and of dimensions as specified.

(d) The brace timbers shall be through bolted and tightly drawn with three-quarter (¾) inch bolts, having washers on each end of the bolt. The single line of bracing on the middle row of piles shall be placed alternately on opposite sides of the piles in each double panel so that one bolt will hold at the lap.

(e) The bracing at the tops of the piles, both transversely and longitudinally, shall be done before weaving of the mattress is begun and if stage of river is such that the lower bracing will not materially interfere with weaving of the mattress, the lower bracing shall also be placed. If the lower bracing cannot be placed without interfering with weaving of the mattress, there shall be temporary bracing applied if needed in addition to the top bracing to hold piling in proper position and the permanent bracing applied after the mattress is sunk.

8. **Screens.**—(a) A continuous row of poles is to be laid on the mattress after it is woven and securely fastened to it with No. 9 galvanized wire in contact with the inside of the bank row of piling. The dike shall then be screened with willow or cottonwood poles, spaced about one-foot centers along the bank side of the dike for its entire length. The butt ends of the poles shall be sharpened and driven through the mattress in contact with the longitudinal row of poles and securely nailed to the same. After the mattress has been sunk and thoroughly settled on the bed of the stream, the poles shall be spaced and nailed to the top and bottom lines of longitudinal bracing and sawed off even with the top of the dike. They shall be of such lengths that when the mattress has been thoroughly settled, the diameter of the pole, where nailed to the top bracing, shall not be less than two (2) inches.

(b) After the dike has been finished the stream row of piling shall be sheathed on the outside and between the top and bottom lines of bracing with four (4) by eight (8) inch timbers twenty-two (22) feet long.

9. **Header.**—As soon as the dike has been started and the first bents have been braced, a header shall be built close up against the first bents. A trench about thirty (30) feet square shall be excavated between the pile bents and the top of the slope, to the level of extreme low water in the stream, into which the edge of the dike mattress shall be sunk. The hole shall then be refilled with alternate layers of brush and stone, each three-foot layer of brush to be covered with a closely packed layer of one-man stones, to the height of two feet above the top of the dike in order to allow for settlement. The cost of the header shall be included in the price bid per linear foot of dike.

10. **Bankhead and Revetment.**—Above the upstream end of the dike, a bankhead and revetment, as hereinafter described, shall be built and form an integral part of the dike. The cost to the Railway Company for same shall be a lump sum price as bid by the Contractor for said bankhead and revetment.

Above the dike mattress and immediately adjacent to same the river bank shall be sloped to a slope not to exceed three horizontal to one vertical for distance of about seventy (70) feet from upstream end of dike mattress. The high point of surface of said slope to be at least 36 inches below extreme low water of river; thence a hole in river bank not less than thirty (30) feet wide parallel with bank of river and extending streamward sufficient distance to extend into extreme low water shall be excavated. The bottom of same to be as low as extreme low water on river bank and river side to be at least 48 inches below extreme low water in river. The entire area of bottom of hole shall be paved with good heavy-one-man stone. Then from upstream side of bankhead a standard mattress shall be laid, the shore edge of same overlapping on stone paving in bottom of hole a distance necessary to prevent any chance of scouring, said mattress shall be of such length that the distance measured along the slope and bottom of hole from the upstream side of bankhead to junction with upstream end of dike mattress shall not be less than one hundred (100) feet. The hole shall then be filled with alternate layers of brush and stone, each layer of brush being not more than three (3) feet thick and covered with closely packed layer of one-man stone. The stream or river side of brush and stone filling of bankhead is to extend over and rest upon shore edge of mattress a sufficient distance to provide a good substantial bond between bankhead and mattress.

The pavement shall consist of stone, rectangular in shape, laid on edge parallel to the bank of the stream and shall be not less than one-foot thick measured normal to the slope. It shall be a continuation of the final layer of stone in bankhead and shall extend not less than eighteen (18) inches riverward from the inshore edge of the mattress. Beyond this a strip of mattress twelve (12) feet wide shall be covered with a compact layer of stone one-foot thick by casting into the water. Previous to paving, the inshore edge of the mattress shall be filled with spalls or quarry chips flush with the top of the mattress and running out to zero thickness six feet up the slope. After the pavement is laid, spalls and quarry chips shall be spread over the surface to fill all interstices. The mattress shall be the standard mattress hereinbefore described, and shall be well weighted with stone. The paving and mattress shall flare upstream from a line normal to the bank and the downstream edge shall be connected to the dike mattress in such manner that it will be a continuation of the dike mattress.

11. **Measurement.**—The length of the diversion dike shall be measured on a straight line of one elevation along its center from the center of the first bent upstream to the center of the last bent downstream, and payment will be made at the price bid per linear foot for the total length to the nearest foot as thus measured.

12. **Final Examination and Acceptance.**—As soon as possible after the completion of the entire work it will be thoroughly inspected by the Engineer, and if found to be constructed in accordance with the plans and specifications, and is otherwise satisfactory, will be finally accepted. All work not fully in accordance with the specifications, shall be repaired to the satisfaction of the Engineer, at the Contractor's own expense, and final payment will be retained until the work has been satisfactorily completed.

13. **Conduct of the Work.**—(a) The contractor will use due diligence and despatch in the execution of the work to the end that the work will be completed in a first class and workmanlike manner. He may be required to suspend work at any time when, for any reason, the stage of the river, its velocity, or the presence of drift, appear to be detrimental to the best results.

(b) It is mutually understood that time is the essence of the contract, and that the work shall be completed in the quickest time possible; and the Contractor will be required to maintain a force sufficient to complete the work in the shortest time possible.

(c) The Contractor shall familiarize himself with the regulations of the Department of War of the United States as affecting the control of inland waterways and shall not do, or permit to be done, anything or operation that shall be in confiict with said regulations. During the progress of the work, he shall not cause to be dumped, thrown overboard, sunk or misplaced any material, plant, machinery or appliances, that may cause a dangerous obstruction in channel of the river, and he shall promptly remove any such article upon request of the Engineer.

(d) Should it become necessary to occupy private property in the execution of the proposed work, the Contractor shall obtain the written consent of the owners before entering upon said property, and shall relieve the Railway Company from liability for the use or misuse of said property.

(e) The Contractor shall provide, as becomes necessary, proper lights each night, between the hours of sunset and sunrise, on all floating plant connected with the work, and shall be responsible for all damages resulting from any neglect or failure in this

respect. If work at night is permitted by the Engineer, the Contractor shall maintain, from sunset to sunrise, such lights on or about his plant which may be deemed necessary for the proper observation of the construction operations.

14. **Minor Modifications.**—It is the object and intent of the plans and specifications to produce a diversion dike complete in every respect. Should any minor changes in the execution of the work be deemed necessary or expedient to carry out the intent of the contract, the Company reserves the right to order such changes, provided the unit cost of the Contractor for doing the work shall not be increased thereby. No change, which will materially affect the cost of doing the work, shall be made, and no greater or lesser unit price paid, except upon formal written agreement between the parties to the contract.

15. **Inspection.**—The work will be conducted under the general direction of the Engineer, whose Inspector, appointed by him, shall enforce a strict compliance with the terms of the contract, but the presence of the Inspector shall not relieve the Contractor of any responsibility for the proper execution of the work. He shall furnish all facilities such as the use of boats, boatmen, laborers and materials, forming a part of the ordinary and usual equipment, as may be reasonably necessary, in inspecting and supervising the work, and it shall be understood that the cost of meeting all these requirements must be included in the price bid.

Appendix D

(5) TYPES OF BULKHEADS, JETTIES AND SEAWALLS, GIVING CROSS-SECTION OF EACH AND STATING THE PURPOSE WHICH THEY SERVE, INCLUDING COMPARISONS OF FIRST COST, SERVICE LIFE AND MAINTENANCE COST OF THE VARIOUS TYPES

W. G. Brown, Chairman, Sub-Committee; R. E. Fristoe, H. F. Sharpley.

Your Committee has collected quite a mass of data from which a full report will be made next year.

Having this in mind, your Committee has devoted its efforts to collection of data for study and assimilation into a comprehensive report, and can now only report progress, with the request that the subject be continued.

Appendix E

(6) TYPES OF FENDER SYSTEMS FOR PROTECTING WHARVES AND RECOMMEND SUITABLE USES FOR EACH, INCLUDING COMPARISONS OF FIRST COST, SERVICE LIFE AND MAINTENANCE COST OF THE VARIOUS TYPES

Benjamin Elkind, Chairman, Sub-Committee; W. G. Brown, R. E. Fristoe, E. H. Roth, C. U. Smith.

Fenders prevent injury by abrasion, avoid damage caused by chafing of vessels against wharves, absorb the energy of impact of vessels coming in contact with wharves and protect the structures from violent sea action in exposed locations. Fenders are fitted so that they can readily be removed for repair and replacement.

The design of fenders is partly of a local nature and there is much scope for the exercise of individual judgment. Dangerous shore eddies, range and duration of tide, absence or presence of waves, swells, currents and ice, existence of worms and insects which attack timber, etc., are purely local. The design of fenders depends on the types of the wharf to be protected, the manner of berthing, the operation of loading and discharging cargo, and the size of the vessel.

A vessel weighing 5,000 tons and moving at a rate of one-half (½) mile an hour has a kinetic energy of about 45-foot-tons. With double the weight and velocity, the energy is almost 340 foot tons. The fenders must expend this amount of work without injury to either the ship or the wharf. Wooden pile structures because of their elasticity are generally protected by fenders against abrasion. Steel, masonry and concrete wharves are usually provided with fenders with sufficient give to save the main structure from shock of vessels coming alongside. There are many examples, however, of rigid wharves on which the fenders are compressible only to the extent furnished by timber fixed or suspended from the face of the structure.

Fenders are grouped into three (3) general types—fixed, spring, and floating.

Fixed Fenders

Fixed fenders may be constructed of piles, vertical or horizontal strips or sheathing or a combination of all or any of the foregoing. Long horizontal strips of heavy timber are not desirable. Vertical chocks should be fitted in at frequent intervals to prevent tugs or similar vessels having considerable sheer from catching under the horizontal strips and thus ripping them off. The outer corners of piers are usually protected by heavy clusters of fender piles or by separate pile clusters and are kept in place by chains or wrapped with wire cable, rather than bolts, to facilitate replacement. White oak piles where obtainable, are generally used in fenders as they better resist abrasion.

Timber is subject to dry and wet rot and to the depredations of worms and insects. Dry rot is a disintegration of the fibres accompanied by the growth of a fungus. It is due to, and accelerated by, inadequate ventilation, and the only efficient preventative is thorough ventilation. Wet rot is a decomposition of the fibres under moisture, and to prevent this it is essential to avoid water pockets and to have a rapid runoff. Destructive marine life of one form or another thrive in nearly all salt and brackish water harbors in this country. The usual practice is to impregnate the timber to a sufficient depth with a preservative to resist the action of these influences.

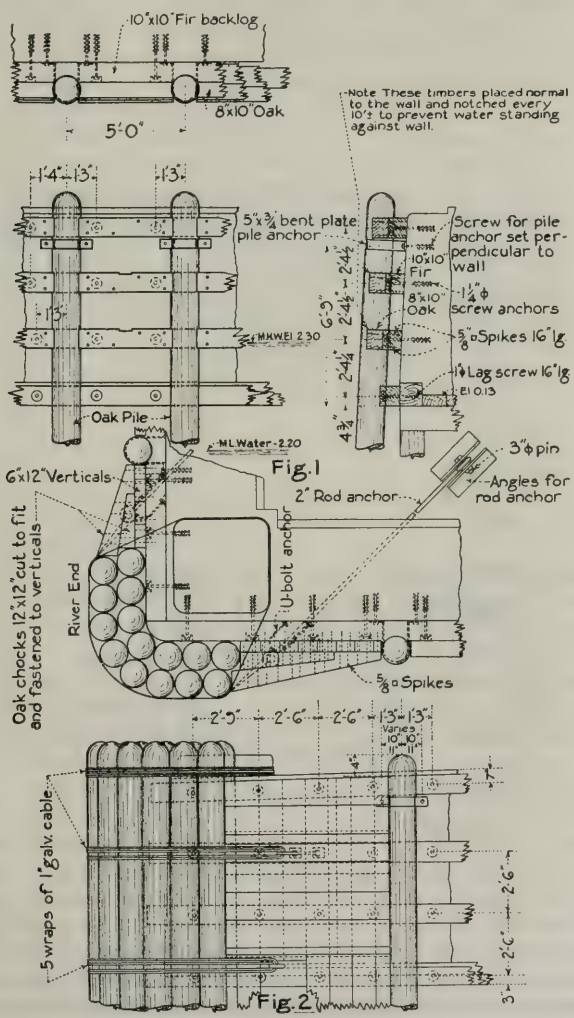
On the Great Lakes where tides and currents do not enter into navigation problems to a great extent, the practice has been to use very simple fender systems, even going so far at times as to construct a concrete docking face with a steel rail imbedded in the face as a guard. Some docks have one or two courses of oak fenders set into the face of the concrete and the theory appears to be that the boat crews must handle their vessel at such speeds as to protect themselves in berthing.

During the past ten years the Lake Carriers Association have been recommending that a wood fender be secured to or set into the concrete fender to afford a buffer for the vessels. Some of the newer docks are being built with an oak timber varying from 16 in. to 24 in. in width set into the concrete fender to protect the vessel sides. These oak pieces are held in place by bolts set in the concrete, the nuts being countersunk in a recess to protect them from damage by vessels. This permits the replacement of the timbers when worn out. On some of the older docks as well as the lock walls of the canal at Sault Ste. Marie, Mich., oak fender wales are being applied, the most acceptable method being the drilling of the face of the fender wall and anchoring with expansion bolts, two 4-in. × 4-in. steel angles 12 in. apart. A 12-in. × 12-in. oak timber is placed between these angles and secured by bolting the timber through the two angles. Two lines of these timbers are placed 12 in. apart and a third timber secured between the first two by vertical bolts. This gives a 3-ft. wide wood fender to protect the vessel.

In some instances on the Great Lakes, wood fenders have been applied to old structures by fastening them with expansion bolts drilled into the concrete, countersinking the nut into the timber as outlined above. These wood fenders have a life of approximately

10 years, depending upon the density of the traffic. In addition to the above, pile clusters have been driven at the outer corners of docks to prevent the vessels from striking the dock and to be used by vessels to lie against in turning at the end of the dock. These pile clusters are wrapped with old wire cable. The piles should be treated above the water line. These pile clusters fail by breaking off at the ground line and are hard to replace because the stubbs cannot be jetted out without danger of undermining the foundation of the dock. By treating the piles in this manner it is to be expected that they will break off in the treated area.

Fig. 1 and 2 illustrate the latest fender construction of steamship wharves in New York Harbor. This type was used in a recently completed Erie Railroad structure in Jersey City known as Pier No. 8. The wharf is 1,000 feet long and 70 feet wide and is



enclosed with a concrete wall, retaining a cinder fill on timber decking, supported on untreated timber piles. The superstructure consists of a three-story steel frame shed and two (2) service tracks extending the full length. The depth is maintained to 33 feet below mean low water level. Scows, tugs and ocean freighters are handled at this pier. All the timber, except the backlogs, in the fenders are white oak. The timber is untreated except for the pile tops which are protected with white lead and oil paint. This

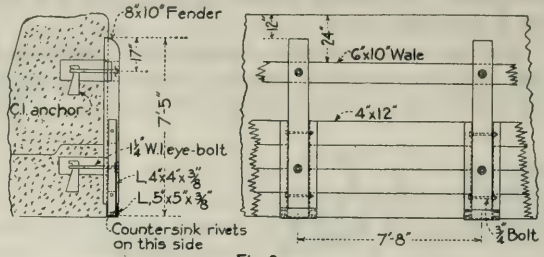


Fig. 3

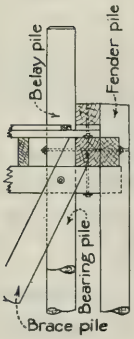


Fig. 4

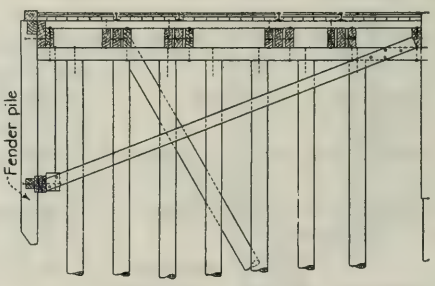


Fig. 5

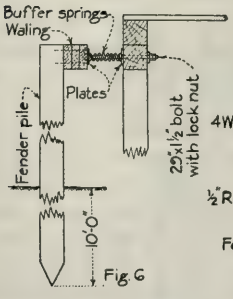


Fig. 6

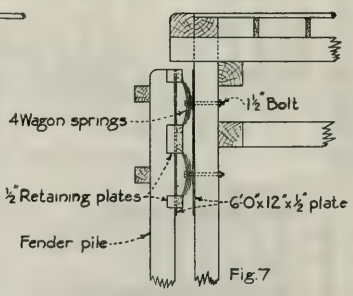


Fig. 7

harbor, on account of the sewage, is not infested with marine borers. The portion of the piles above low water is the only part which decays but was not impregnated on account of the fire risk. It will be noted that the river end has vertical oak strips to resist shearing from tugs, scows and square cornered vessels. This is not necessary along the sides of wharves on account of the narrow slip. The fender system is fastened to the concrete wall of the structure with screw anchors which permit ready replacement. The oak fender strip is securely fastened by spikes to the backlogs.

Fig. 3 illustrates a removable fender for the concrete Bird Island Pier at Buffalo, N. Y. On account of the severe ice conditions and the shutdown of navigation in winter, it is desirable that the timber fenders be readily removable. The lower part of the wall proper is of precast concrete blocks and the upper of concrete poured in place. The fender system consists of vertical 8 in. × 10 in. timbers, with an upper 6 in. × 10 in. continuous wale and a rubbing face of 4 in. × 12 in. boards. Recesses are cast in the blocks and left in the upper section of the wall at every fender, and at these recesses an iron hook is embedded protruding up into the opening. Every fender has two looped bolts passing through it which hook over the embedded iron, the fender being cushioned from the concrete face by the interposed horizontal wale. Alongside of each fender are fastened structural angles, forming grooves which act as guides for the rubbing timbers. The fender can be taken down by being lifted in sections from the hooks and similarly returned when its protection is again required. Rubbing boards can be replaced by slipping the damaged unit out of the guides and dropping a new one in, without any carpenter work or repair on any other part of the structure. (For additional information see Engineering News–Record, August 12, 1920).

Fig. 4 illustrates fender construction as more commonly used. It shows the framing, fender pile and belay pile as generally used for tieing up boats in 30 to 40 feet of water where tides and currents are not usually severe.

Fig. 5 illustrates the use of short or stub fenders by the Oakland Port Commission, Oakland, Cal., where the water is sufficiently deep to justify hanging the fenders from the wharf. The dummy piles reach below low water and have the bottom end beveled to prevent possible uplift from floating timber or a boat guard rail. Sometimes, to take the wear from the rubbing of the guard rails of the boats, untreated sheathing 6 in. × 8 in. × 20 ft. is spiked at 45 degrees with the horizontal to the dummy piles which hang from the ribbing and alternate with the treated piles on the inside face of the slip.

Spring Fenders

Spring fenders employ the use of coil springs or groups of heavy springs, where rough water or strong current is prevalent; this type permits vessels coming along side without damaging the structure.

Fig. 6 illustrates an example used at Los Angeles Harbor, Cal. The fender piles are supported from the cap timbers by coil springs, the piles being driven 8 ft. apart along the jetty, the pile heads bearing against a waling composed of three timbers bolted together. Between this waling and the capping of the jetty, three coil buffer springs were placed. The springs were fitted with a ½-in. thick mild steel bearing back and front, the plates being 8 in. × 12 in. The diameters of the coils are ⅝-in., ¾-in. and 1-in. respectively. Though the springs appear somewhat light, the arrangement has proven satisfactory at this location.

Fig. 7 is an example of an alternative arrangement in which leaf springs are used in groups of four. The load sustained by each spring being four tons, the total resistance available ultimately to bring the vessel gently to rest is 16 tons at each bay of 10 feet.

Floating Fenders

A floating fender often consists of rolling logs or of single or made-up timbers fastened at the ends with lines or chains fixed to the side of the wharves. Floating fenders consisting of round logs or rafts built up of timber are more suitable for masonry walls than for pile structures, as they cause rapid wear of the piles. This is particularly un-

desirable where the piles are treated, as the marine borers attack them as soon as the treated exterior portion is worn through. Compressible fenders made of bundles of saplings bound with wire are used on the large concrete pile pier at Halifax.

Appendix F

(7) WAREHOUSE PIERS, COAL AND ORE PIERS, CAR FLOAT PIERS AND OTHERS, WITH RECOMMENDATIONS AS TO THE TYPE SUITABLE FOR USE UNDER VARYING CONDITIONS, INCLUDING COMPARISONS OF FIRST COST, SERVICE LIFE AND MAINTENANCE COST OF THE VARIOUS TYPES

R. C. Young, Chairman, Sub-Committee; W. G. Brown, E. H. Roth, H. F. Sharpley.

Coal and Ore Piers

From the beginning coal and ore wharves or piers on the Great Lakes have been commonly called docks.

The first dock designed for the shipment of iron ore was built at Marquette Harbor in 1855. It was built about 4½ ft. above the water in the form of a wharf. The ore was wheeled aboard the vessels with wheel barrows 30 men loading a 300-ton vessel in from three to six days. The ore was transported to the dock in 4-wheeled flat bottomed cars carrying about three tons each and drawn by mules. The ore was shoveled from the cars from a trestle about 8 ft. above the deck of the dock.

There are two general classes of coal and ore docks (or piers), viz.: Docks designed to load ore or coal into vessels and those designed to receive the same commodities at the delivery port.

Ore Loading Docks on the Great Lakes

These docks are so constructed that the hopper bottom cars into which the ore is loaded at the mines are pushed to the top of the dock over an inclined approach, dumped into pockets and from there through chutes into the vessel.

The first ore dock of this nature was built of timber in Marquette, Mich., in 1857 and the deck was 25 ft. above the water. As the small sailing vessels were replaced by larger sailing vessels and steamers the size of the timber docks was increased to a height of 73 ft. above the water. About 1911 the D.M.&N. Ry. at Duluth, Minn. and the D.&I.R. Ry. at Two Harbors, Minn. began to replace their timber docks with steel structures placed on concrete foundations. The same year the Great Northern Railway built a similar steel ore dock at Allouez Bay, Wisconsin. In 1912 the Lake Superior and Ishpeming Railway built the first reinforced concrete dock to replace their timber structure. Since 1912 the ore dock construction on the Great Lakes has been largely of a permanent nature. The Northern Pacific, the Soo Line and D.S.S.&A. Ry. have all built reinforced concrete docks. These are of a different design, however, than the one built by the L.S.&I. Ry. and now most of the ore shipping docks on the Great Lakes are either of steel with concrete foundations or all of reinforced concrete. Other railroad companies, however, are still building modern, electrically operated docks of timber which are quite efficient and economical.

These docks are composed of two rows of pockets or bins sloping from the center toward the outside; the slope of the pocket bottom varies from 45 degrees to 48 degrees.

These pockets are spaced 12 ft. center to center longitudinally and usually have two railroad tracks over each pocket or four tracks in all. The pockets hold from 250 to 400 gross tons of iron ore each. Each pocket is equipped with a steel chute about 32 ft. long and about 7 ft. wide at dock end and 5 ft. wide at delivery end. The flow of ore is controlled by gates or doors, both the chute and pocket door are operated by an electric motor, each motor is arranged to operate from 6 to 10 chutes and pocket doors. These docks are well lighted by electricity so that loading can be carried on during the entire 24 hours.

The general dimensions of the permanent ore docks are—

Height from deck to water	75 ft. to 85 ft.
Width out to out at deck	54 ft. to 62½ ft.
Width out to out at fender	60 ft. to 68 ft.

The number of pockets vary from 150 to 384.

Foundations

The foundations of the permanent docks are of three general types, viz.:

Cribs.—Where the material in the harbor is clay, the site is dredged to a safe point below any possible expected harbor depth and two lines of timber cribs built to the height of low water datum, one on each side of the dock. These cribs are filled with rock which is covered with canvas and concrete slab foundation placed on each side and tied together frequently with concrete beams. The vessel fenders are built on each side as a part of the concrete slabs and the piers supporting the dock columns are placed thereon.

Open Pile Foundation.—The piles in this foundation are driven in bents about 4 ft. apart; at every alternate bent batter piles are driven to take care of the sway. About every 120 ft. rectangular cribs are formed by driving sheet piling the width of the dock and about 24 ft. lengthwise of the dock. These cribs are tied together with rods and filled with sand or rock. The piling and sheet piling is cut off to low water datum and a reinforced concrete slab placed on each side and tied together frequently with reinforced concrete beams. The vessel fender is built into this slab as are the piers carrying the columns supporting the superstructure.

Closed Type Pile Foundations.—In this type the piles are driven the same as in the open type, wale timbers are placed around the entire foundation and it is enclosed with sheet piling, either wood or steel. The foundation is tied together with 1½ in. steel turnbuckle rods; the piling and sheet piling cut off at low water datum and the whole foundation filled with sand dredged from the harbor.

In the case of the L.S.&I. dock, the entire pile foundation is covered by a combined slab and fender while some of the other docks have a slab the same as described in the open pile foundation and crib foundations.

All piling and timber is untreated and is safe from decay indefinitely below a point 15 in. above mean water level datum.

At Norfolk, Va., the Norfolk and Western Railway have built similar piers for loading coal into vessels, as follows:

Lambert's Point, Virginia—Facilities—

Coal Pier No. 4

Length—1200 ft.
Width—68 ft.
Height above mean low tide—91.5 ft.
No. of chutes on each side—31
Length of adjustable chutes—33 ft.
Spacing center to center of pockets—30 ft.
Capacity of pockets in tons—144 each.
Height of bottom of pockets above mean low tide—68 ft.

LIST OF ORE LOADING DOCKS ON THE GREAT LAKES

RAILWAY	LOCATION	Dock No.	Number of pockets	Capacity per pocket cars	Storage Capacity Gross tons	Cu.ft. per pocket to bottom of stringers	Height water to center of hinge hole	Height water to deck of dock	Width of dock outside to outside of partition posts	Length of spouts	Length of Dock	Angle of Pocket	Date of Reconstruction
Chicago & Northwestern Ry.	Escanaba, Mich.	5	370	5 at 50 tons	92500	4142	37'9-5/8"	70' 9"	51' 6"	32' 1½"	2220'	45°-0'	1910
" " "	" "	6	320	5 " " "	80000	4260	40' 0"	73' 1/2"	51' 6"	35' 4½"	1920'	45°-0'	1925
										234-30'0"			234 pockets 1913
" " "	Ashland, Wis.	1	290	5 " " "	72500	4100	39'-1/4"	72' 1"	49' 6"	56-32'1½"	1740'	45°-0'	56 " 1916
										78-30'0"			78 " 1908
" " "	" "	2	278	4 " " "	55600	3550	39'-2½"	70' 4½"	49' 6"	200-32'1½"	1668'	45°-0'	200 " 1924
													200 " 1917
" " "	" "	3	340	5 " " "	85000	4260	40'-4-3/4"	73' 5½"	51' 6"	35'-4½"	2040'	45°-0'	140 " 1921
	Total		1598		385600								
Duluth, Missabe & Northern Ry. Co.	Two Harbors, Minn.	1	224	5 at 50 tons	56000	4532	39'-3"	75' 2"	51' 8"	34'-0"	1376'	48°-0'	1912 x
" " " " "	" " "	2	228	6 " " "	68400	5360	40'-3-7/8"	80' -0"	56' 8"	35'-0"	1400'	48°-0'	1916 x
" " " " "	" " "	6	148	6 " " "	44400	4820	40'-0"	74' 2½"	51' 3/4"	34'-0"	920'	45°-0'	1916 and 1924 x
	Total		600		168800								
" " " " "	Duluth, Minn.	5	384	6 at 50 tons	115200	5313	40'-8"	80'-5"	56' 0"	36'-0"	2304'	47°-30'	1915 x
" " " " "	" "	6	384	8 " " "	153600	6560	40'4-7/8"	84'-5"	60' 0"	36'-0"	2304'	47°-30'	1919 x
	Total		768		268800								
Great Northern Railway Co.	Superior, Wis.	1	374	7 at 50 tons	130900	5620	41'-2"	80' 8"	56' 0"	36'-0"	2244'	47°-30'	1926-27-28 x
" " " "	" "	2	350	7 " " "	122500	5620	41'-0"	80' 6"	56' 0"	36'-0"	2100'	47°-30'	1923 x
							38'-9"						160 pockets 1918
" " " "	" "	3	326	6 " " "	97800	5100	38'-9½"	77' 8"	59' 8"	34'-0"	1956'	47°-30'	166 " 1921
" " " "	" "	4	302	6 " " "	90600	5035	40'-2"	75' 0"	62' 6"	34'-6"	1812'	47°-30'	1911 x
	Total		1352		441800								
Northern Pacific Ry. Co.	Superior, Wis.	1	102	7 at 50 tons	35700	5490	40'-6"	80' 0"	57' 2"	34'-0"	612'	47°- 30'	1913 x
	Extn.	1	100	7 " " "	35000	5600	39'-9"	80' 0"	59' 2"	34'-1/8"	600'	47°- 30'	1917 #
	2nd Extn.	1	108	7 " " "	37800	5600	39'-7"	80' 0"	59' 2"	34'-1/8"	648'	47°- 30'	1926 #
	Total		310		108500								
Duluth, South Shore & Atlantic Ry.	Marquette, Mich.	6	150	5 at 75 tons or 7 " 50 tons	56250	5940	43'-3"	85'-7"	59'-0"	36'-0"	900'	47°-30'	1931 #
													150 pockets 1917 #
Minn., St.Paul & Sault Ste. Marie Ry.	Ashland, Wis.	2	300	7 " 50 tons	105000	5100	42'-0"	81'-0"	59'-0"	34'-6"	1800'	47°-30'	150 pockets 1924 #
Lake Superior & Ishpeming R. R. Co.	Marquette, Mich.	2	200	5 " 50 tons	50000	4590	43'-0"	75'-0"	54'-0"	35'-0"	1200'	45°-0'	1912 x
Chicago, Milw., St.Paul & Pacific Ry.	N. Escanaba, Mich.			3 " 50 tons						120 at 27'			120 pockets 1901
		1	240	1 " 25 "	42000	2900	40'-2-3/4"	66'-6"	52' 0"	120 " 29'	1500'	45°-0'	120 " 1902
" " " " "	" "	2	240	4 " 50 "	48000	3150	40'-11½"	69'-2"	54' 0"	30'-4½"	1500'	45°-0'	1906
	Total		480		90000								

x Steel and concrete
Reinforced concrete

The variation of the tide and the listing of the vessels is taken care of by the adjustable chutes. These chutes are raised and lowered as the occasion demands by manually operated windlass.

The road cars are pulled upon what is known as an electrically operated dumper by barney cars, thence the road cars are dumped into pier cars, each holding 100 tons. These pier cars are electrically operated and are moved forward under their own power to an electric elevator where they are elevated on top of the pier at an elevation of 91.5 ft. above mean low tide. Pier cars are thence moved forward to the various pockets and are dumped automatically by an air operated tripping device. There are two dumpers located on the land end of this pier which have a capacity of dumping one road car about every 1¼ minutes.

Coal Pier No. 3

Length—860 ft.
Width—58.5 ft.
Height above mean low tide—77 ft.
No. of chutes on each side—30 ft.
Length of telescopic chutes—33 ft.
Spacing center to center of pockets—25 ft.
Capacity of pockets in tons on each side—10 tons.
Height of bottom of pockets above mean low tide—44 ft.

This coal pier has one electrically operated dumper on the land end and can be operated similar to the above mentioned coal pier No. 4. However, in recent years the Company has arranged to operate road cars directly upon this pier from where the road cars are dumped directly into the pockets, from which pockets the coal is transferred to the vessels by telescopic chutes.

Coal Pier No. 3 has a vessel docking capacity of 4 of the smaller type or 2 larger and 2 smaller ocean vessels, while Coal Pier No. 4 has a vessel docking capacity of 4 of the larger oceangoing vessels.

The railway company has 3 at Lambert's Point, Pier S being described below.

Length—1200 ft.
Width—222 ft., including two 7 ft. apron platforms on each side.
Housed width—208 ft.
On the center of this house are 4 depressed tracks, capacity 100 cars.
On each side of the house are adjustable ramps which can be raised or lowered according to the listing of the vessels. These ramps are equipped with escalators.
Docking capacity on each side is two vessels and if necessary one on the outer end.

At Sewell's Point, Virginia, the railroad also owns and operates two warehouses and one grain elevator.

Grain elevator storage capacity in bushels is 750,000.
Length of docking space—1400 ft.
Maximum capacity of grain handling per hour—50,000 bushels.
Height of grain galleries above mean sea level datum—71 ft.
No. of chutes for loading vessels—3.
Warehouse pier at Sewell's Point docking space—2400 ft.
Width of houses—99 ft.
Car capacity of tracks in rear of the two houses—120.
Car capacity of tracks on apron platform—224.

The warehouses at Sewell's Point are reinforced concrete type construction supported by concrete piles, while the warehouses at Lambert's Point are supported on steel cylinders filled with concrete. These steel cylinders support the main columns of the structure proper. The floor system of the entire warehouse is supported on creosoted wooden piles varying in length from 75 ft. to 110 ft.

The coal piers are supported by steel cylinders filled with concrete and the main floor system is supported on creosoted wooden piling throughout.

For the oceangoing vessels the Railway Company maintains the slips to a depth of 35-ft. below mean low tide, and for coastwise vessels a depth of 25-ft.

Ore Unloading Docks and Coal Unloading Docks

These docks are of the same general type and can be described very briefly. They are usually designed to carry an unloading crane. They can be built either parallel to shore in the form of a wharf or at right angles to shore in the form of a pier. If in the form of a pier, the general method of construction is to drive a row of piling about 4 ft. centers enclosing the proposed structure, a row of Wakefield or other approved sheet piling is then driven enclosing the whole area. The foundation is then tied together with 1½ inch turnbuckle rods below the water line. If it is to be a wood structure the piles and sheet piles can be cut off about 7 ft. above the water level and suitable wale strips be applied for vessel fenders; the whole structure is then filled with sand by use of a dredge.

The area is decked or not, depending upon the use to be made of it.

The foundations for crane rails can be made by driving piles for supports to the crane rail timbers.

A dock can be constructed in this manner and used successfully until the timber and piling above water is decayed. It can then be cut off at water line, a few piles driven to support the back of the concrete wall and a concrete fender wall can be built from water line to top of dock which makes a permanent structure, or if a permanent structure is contemplated in the first place, the piling can be cut off at the water level and the concrete fender built in the first instance.

If the dock is to be built parallel to the shore, the construction will be the same as above except that anchor piling should be driven about 30 ft. back of the face of the dock and the anchor rods installed there to hold the face of the dock from bulging.

In rivers or harbors where the waterway cannot be restricted docks are sometimes built with a reinforced concrete floor resting on piles so as to allow the water to pass under it. The fender or vessel wale is so designed that the strain or shock is carried through the fender and floor to the shore. The floor is filled with suitable material to the top of the fender. Various kinds of unloading cranes or bridges are used to remove ore or coal from the hold of the vessel, clam shell buckets from 3 to 15 tons capacity are used. At Alpena a limestone dock or pier, similar to the iron ore docks is used to load limestone into vessels. At Inland Harbor, Michigan, the Inland Steel Company has a dock or pier for loading crushed stone into vessels. This structure is similar in construction to the piers built for unloading of iron ore and coal, except that it is somewhat higher and has trap doors in the deck which allows the different grades of crushed stone to drop through onto a belt conveyor running lengthwise with the pier. This conveyor deposits the stone on to lateral conveyors which carry the stone into the vessel.

At many of the lower lake ports docks for loading coal into vessels are built similar to the coal and ore unloading docks, except they are equipped with mechanism for lifting up the gondola cars of coal, turning them bottom up and dumping them into a container which is then lowered into the vessel hold and dumped.

Comparative Costs

In 1911, a study was made of construction and maintenance costs of three types of iron ore loading docks on the Great Lakes, not including the approach structure, with the following results:

Cost—	Timber	100 per cent
	Concrete	167 per cent
	Steel	187 per cent

Maintenance over a 30 year period, which contemplates a life of from 15 years to 20 years for a timber dock and writing off the entire investment in 30 years is as follows:

Maintenance—Timber	100	per cent
Concrete	70	per cent
Steel	76	per cent

Coal and Ore Piers on the Pacific Coast

The superstructure of coal and ore piers is not here discussed as the design is more or less individual as determined by the requirements of each location. The foundation must be planned for heavier loads than is the general practice in wharf design, and this added foundation strength is often secured by placing timber cribs filled with rock.

Another type of foundation used for ore docks is thickly driven piling. A concrete bulkhead may be constructed on the channel side and strengthened with tie rods carried across to piling on the opposite side of the pier. The pier may be built on piles driven so close together as to form suitable foundation for a reinforced concrete mat or blanket over the entire foundation area. If the piles are driven in water, sand may be filled in to low water or to the height at which the piling can be conveniently cut off for the placing of a reinforced concrete blanket.

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Eng. News Rec.—Sept. 16, 1926, Vol. 97, No. 12, p. 455–457

Great Northern Ore Dock No. 1
Eng. News Rec.—Sept. 23, 1926, Vol. 97, No. 13, p. 496–498

Ore Docks
Scien. American—March 1924.

Norfolk & Western Coal Pier No. 4
Late in 1912 or early in 1913; also see Ports & Terminal Facilities, by McClure, second edition, p. 344–345

For Virginian and Chesapeake & Ohio facilities, consult
Wellman–Seaver–Morgan Co., Cleveland, Ohio.

Appendix G

(10) ECONOMIC PRINCIPLES INVOLVED IN CLEARANCES OVER NAVIGABLE WATERWAYS

Robert H. Ford, Chairman, Sub-Committee; D. J. Brumley, G. S. Fanning, W. D. Faucette, R. A. Feldes, F. G. Jonah, C. S. Kirkpatrick, G. J. Ray, J. E. Willoughby.

The actual and proposed development of inland waterways in the United States has the effect of placing an increased burden upon the operations of land transportation and facilities. This can usually be traced to excessive clearance requirements for bridges spanning inland streams which are considered as navigable.

A study of typical cases has been made and in practically every instance it has been found that the clearances required and demanded are unduly excessive and unnecessary in the light of modern tendencies in watercraft design, construction and operation.

It has also been found that the requirements for these unnecessary clearances largely result either from a lack of proper data or from a failure to appreciate the various factors which must be considered before proper clearances can be determined in the interest of both land and water transportation.

Proper clearances for naturally navigable streams are those which will not unduly interfere with the operation of either land or water transportation, cause unwise expenditures to be made for physical readjustments, or place burdensome restrictions on their future expansion. There must be an economic balance in the interest of both forms of transportation.

While adequate information is not yet available to enable a forecast to be made as to the result of these burdensome restrictions on rail transportation, from certain data which has been made available to us we conclude that the excess annual cost to the railroads of the United States represents a sum, which when capitalized at 5 per cent, amounts to at least Two Hundred Million Dollars.

We are collecting information on these and similar questions and expect to report a formula which can be used as a guide to a proper approach to problems of this character and thus permit a better understanding of the subject than appears generally to exist at present. We are also contacting with various other scientific organizations which are working on various aspects of this problem.

Appendix H

(11) COST TO RAILWAYS FOR CONSTRUCTION, MAINTENANCE AND OPERATION OF BRIDGES OVER NAVIGABLE WATERWAYS

(a) in the natural condition of stream.
(b) additional costs brought about by the enlargement of the capacity of the streams over and above their natural conditions.

F. E. Morrow, Chairman, Sub-Committee; W. H. Courtenay, L. G. Curtis, I. W. Geer, G. F. Hand, J. R. Hickox, C. F. Loweth, G. R. Westcott.

Your Committee has only fragmentary and incomplete data covering the costs to railroads as a whole of constructing, operating and maintaining bridges crossing navigable waterways, but it is obvious that such expense is very large. It is also obvious that such expense is large to states, counties, and other local governmental sub-divisions. It is also a well-known fact that in many instances large expenditures have been and are required where the benefits to waterway traffic are negligible.

The cost of the construction, maintenance and operation of bridges over navigable waterways in the United States is fixed by the provisions of the Statutes of the United States pertaining to navigation and navigable waters. Section 491 of Chapter 11—Bridges Over Navigable Waters—reads as follows:

"Approval of and deviation from plans. When, after March 23, 1906 authority is granted by Congress to any persons to construct and maintain a bridge across or over any of the navigable waters of the United States, such bridge shall not be built or commenced until the plans and specifications for its construction, together with such drawings of the proposed construction and such map of the proposed location as may be required for a full understanding of the subject, have been submitted to the Secretary of War and Chief of Engineers for their approval, nor until they shall have approved such plans and specifications and the location of such bridge and accessory works, and when the plans for any bridge to be constructed under the provisions of this chapter, Section 491 to 498, inclusive, have been approved by the Chief of Engineers and by the Secretary of War it shall not be lawful to deviate from such plans, either before or after completion of the structure, unless the modification of such plans has previously been submitted to and received the approval of the Chief of Engineers and of the Secretary of War."

Section 494 of Chapter 11—Bridges Over Navigable Waters—reads as follows:

"Obstruction of navigation; alterations and removals; lights and signals; draws; tolls. No bridge erected or maintained under the provisions of this chapter, Sections 491 to 498, inclusive, shall at any time unreasonably obstruct the free navigation of the waters over which it is constructed, and if any bridge erected in accordance with the provisions of this chapter, Sections 491 to 498, inclusive, shall, in the opinion of the Secretary of War, at any time unreasonably obstruct such navigation, either on account of insufficient height, width of span, or otherwise, or if there be difficulty in passing the draw opening or the drawspan of such bridge by rafts, steamboats or other water craft, it shall be the duty of the Secretary of War, after giving the parties interested reasonable opportunity to be heard, to notify the persons owning or controlling such bridge to so alter the same as to render navigation through or under it reasonably free, easy, and unobstructed, stating in such notice the changes required to be made, and prescribing in each case a reasonable time in which to make such changes, and if at the end of the time so specified the changes so required have not been made, the persons owning or controlling such bridge shall be deemed guilty of a violation of this chapter, Sections 491 to 498, inclusive; and all such alterations shall be made and all such obstructions shall be removed at the expense of the persons owning or operating said bridge. The persons owning or operating any such bridge shall maintain, at their own expense, such lights and other signals thereon as the Secretary of Commerce shall prescribe. If the bridge shall be constructed with a draw, then the draw shall be opened promptly by the persons owning or operating such bridge upon reasonable signal for the passage of boats and other water craft. If tolls shall be charged for the transit over any bridge constructed under the provisions of this chapter, sections 491 to 498, inclusive, of engines, cars, street cars, wagons, carriages, vehicles, animals, foot passengers, or other passengers, such tolls shall be reasonable and just, and the Secretary of War may, at any time, and from time to time, prescribe the reasonable rates of toll for such transit over such bridge, and the rates so prescribed shall be the legal rates and shall be the rates demanded and received for such transit."

The provisions of the statutes are based on the theory that there is an inalienable right inherent in the use of a waterway and that all forms of land transportation must be subordinate to it. In other words, facilities required by all forms of land transportation in crossing a navigable waterway must be provided at the sole cost and expense of the owners thereof, and must conform to any changes made thereafter in the waterway itself or in the waterway traffic.

For the purpose of this report, navigable waterways will be considered in three subdivisions, as follows:

1. Waterways in their natural condition.
2. Natural waterways which are improved by deepening, widening, straightening, or otherwise, or on which the character of waterway traffic is changed by improvements made elsewhere, or by changes in design of vessels or methods of waterway transportation.
3. Artificial waterways.

It seems clear to your Committee that the provisions of the Statutes of the United States now in force are based on an erroneous principle. The principle may have been proper in the early period of this country's existence when waterways were the principal avenues of transportation, but that time is long since past. For many years the inland waterways of the United States have borne but a negligible part of the total inland transportation. The highways and railroads are the main agencies of inland transportation, and true public interest demands that the harbor transportation agencies should not be penalized by being subordinate to a minor agency. Our laws should be modelled on the principle of the greatest good to the largest number and on fairness and equity to all.

In many cases streams originally narrow and shallow, on which only canoes or other small craft could navigate, have been deepened, widened and straightened from time to time so that the entire character of the stream and the navigation thereon has been completely changed. In other cases, the uses of streams have been radically changed by changing connecting channels or by the removal of obstructions elsewhere, or by change in design of vessels or methods of water transportation. In other cases, artificial channels have been constructed, sometimes for purposes other than navigation, which since have been improved for navigation or the character of waterway traffic changed. In some cases, the waterway is changed by constructing locks and dams which raises the water level, causing changes not only in bridges but resulting in damage to other forms of property. Under the present United States laws, the expense of conforming bridges and collateral facilities to meet the changes made in the navigable streams are required to be borne by the owners of those facilities.

Most of the improvements to navigable streams are made for the purpose of providing new or improved waterways for navigation purposes. This navigation usually competes with other forms of transportation. A waterway project should be undertaken only if the total expenditure required to construct, maintain and operate it can be economically justified. It should not be undertaken if only a part of the expenditure (that part now commonly borne by the Federal government) can be economically justified, the remainder of the expenditure to be borne by private interests or some local governmental sub-division.

Your Committee is of the opinion that the following principles are equitable and should govern in providing funds for the construction, maintenance and operation of bridges, including approaches thereto, over navigable waterways:

1. Any agency providing facilities for land transportation when bridging a navigable waterway in its natural state, an improved waterway, or an artificial waterway, should assume the expense (but not more than) of constructing, maintaining and operating the bridge and other collateral facilities reasonably necessary to permit the use of such waterway in its condition at the time the crossing is made.

2. Where an artificial waterway is constructed across existing land transportation routes, the governmental authority in charge of and providing the funds for the waterway project should bear the entire expense of constructing, maintaining and operating bridges and other collateral facilities required on account of such crossing, not only as originally made, but all changes or alterations made thereafter on account of changes in the waterway or the character of traffic on such waterway.

3. When a waterway is improved by widening, straightening, deepening or otherwise, or the character of traffic on the waterway is changed by improvements elsewhere, or by changes in the design of vessels using the waterway, or by changes in methods of waterway transportation, which require changes in the bridges or other collateral facilities carrying land transportation agencies over such waterway, the governmental authority in charge of and providing the funds for the waterway should bear the expense of making such changes in the bridges or other collateral facilities, and the additional expense of maintaining and operating such altered bridges or facilities over and above the expense of the maintenance and operation of the bridges and facilities as they existed before such changes were made.

4. Any agency providing facilities for land transportation, crossing a navigable waterway, requiring, for its own purposes, changes in the bridges carrying it over the waterway, its collateral facilities, or in the waterway itself, the land transportation agency should bear the expense of making such changes, and the additional expense of maintaining and operating such altered bridges or facilities over and above the expense of the maintenance and operation of the bridges and facilities as they existed before such changes were made.

Waterways are only one of several means of inland transportation and it is to the public interest that all of these agencies should bear the expense properly applicable to the providing of the facilities necessary for such transportation agency, and the maintenance and operating expenses properly attributable to it. If this is not done it results in discrimination and the penalizing of one form of transportation to the benefit of some other form. Inasmuch as they are all competing agencies there should be no discrimination.

Therefore, it is the conclusion of your Committee that a change should be made in the present Statutes of the United States to bring about an allocation of the expense of construction, maintenance and operation of bridges over navigable waterways in accordance with the principles herein set forth.

REPORT OF SPECIAL COMMITTEE ON WATERPROOFING OF RAILWAY STRUCTURES

J. A. Lahmer, *Chairman;*
G. E. Boyd,
O. F. Dalstrom,
Hugo Filippi,
L. V. Haegert,
A. C. Irwin,
F. R. Judd,
A. H. Morrill,
G. A. Rodman,
I. L. Simmons,
F. P. Turner,
G. A. Haggander, *Vice-Chairman;*
L. W. Walter,
H. T. Welty,
C. A. Whipple,
Committee.

To the American Railway Engineering Association:

Your Committee presents herewith its report on the following subjects:

(1) Revision of Manual. Nothing to report.

(2) When to waterproof or dampproof and methods to be used (Appendix A).

(3) Waterproofing and dampproofing as applied to existing railway structures. Nothing to report.

(4) Specifications for membrane waterproofing (Appendix B). These specifications are substantially the same as those which were submitted as information a year ago and printed in Bulletin 350. Some minor changes have been made for purpose of simplification and a few to eliminate inconsistencies.

Action Recommended

(2) That the report in Appendix A be received as information.

(4) That specifications in Appendix B be adopted as recommended practice and published in the Manual in place of specifications on pages 1171 to 1180.

Respectfully Submitted,

Special Committee on Waterproofing of Railway Structures,
J. A. Lahmer, *Chairman.*

Appendix A

(2) WHEN TO WATERPROOF OR DAMPPROOF AND METHODS TO BE USED

O. F. Dalstrom, Chairman, Sub-Committee; L. V. Haegert, A. C. Irwin, G. A. Rodman, I. L. Simmons, C. A. Whipple.

For convenience, the following definitions of waterproofing and dampproofing are quoted from A.R.E.A. Bulletin 347, "Revisions and Additions to the Manual" (July, 1932):

Waterproofing.—The treatment of any material or structure to prevent the entrance or passage of water or other liquid under head.

Dampproofing.—The treatment of any material or structure to prevent the entrance or passage of water or other liquid not under head.

PRINCIPLES GOVERNING THE USE OF WATERPROOFING OR DAMPPROOFING OF RAILWAY STRUCTURES

Waterproofing

1. Adequate and effective drainage should be provided to remove water from the waterproofed surface if practicable.

2. Where the range of temperature varies from above freezing to below freezing, the disintegrating effect of frost action on water-saturated masonry must be recognized and adequately guarded against.

Where the temperature does not fall below freezing, the destructive effects of water penetration, but not permeation, are small. In cases of the passage of small quantities of water through parts of structures not subject to freezing temperatures, waterproofing should be provided only as required by appearance of surfaces or use of structure.

3. Waterproofing should not be applied to the face of masonry subject to freezing and thawing, where water reaches that face through the masonry.

4. The materials for waterproofing and the methods of application should be such as to insure that the waterproofing will be retained by bond, anchorage or other adequate means, in its original position as applied to the surface to be waterproofed.

5. Where waterproofing is subject to possible injury from abrasion, pressure, puncture or otherwise, it should be protected with a substantial covering.

6. Waterproofing should be applied where economically justified, considering the use and probable life of the structure and the cost of obtaining adequate watertightness by design and construction.

7. The type of waterproofing should be determined by the use and probable life of the structure, and the cost of renewal of the waterproofing:

(A) Waterproofing of the most durable and effective type should be used on permanent structures:

(a) In locations subject to water or other liquids under a hydrostatic head.
(b) Where repair or renewal is impracticable or prohibitive in cost.
(c) Where certainty of watertightness must be had because of heavy damage if water enters.

(B) Waterproofing specially designed for the purpose should be used where the structure must be protected against liquids containing corrosive and/or disintegrating substances.

8. A waterproofing membrane on the surface adjacent to the water source is the most effective externally applied waterproofing, but difficulties of application and prohibitive cost may sometimes make consideration of some other method advisable.

9. Surface applications on the inner faces of walls for the purpose of waterproofing against external pressure must derive their effectiveness from bond with the masonry or from closing the surface pores. Such applications can generally be considered effective only to prevent seepage under little or no head. Such coatings must be insoluble and unaffected by dampness.

Dampproofing

1. Dampproofing is effective in preventing the accumulation of surface moisture from condensation only in proportion to its temperature-insulating value.

2. Dampproofing will probably not be effective where masonry is subject to moisture saturation accompanied by cycles of freezing and thawing.

3. Ordinary dampproofing is not effective against cracks or openings through the masonry.

4. A frequent fault of one-coat dampproofing is failure to produce a continuous covering free from pin holes. This should be considered in deciding upon the number of coats that should be applied.

5. The purpose and character of dampproofing are not such as to require special protection or covering. Where protection or covering is necessary, the conditions will usually warrant the use of waterproofing.

6. A prime requisite of dampproof covering is that it shall stay in place. Bond with the surface is therefore essential.

7. The selection of materials for dampproofing must include consideration of the effect of extremes of temperature, the effect of the sun's rays, and the physical and chemical effects of the liquid to which they will be subjected.

Specific Cases

Abutments, Piers and Retaining Walls

1. On the assumption that effective drainage has been provided, waterproofing on the back of an abutment or retaining wall is generally not necessary, but dampproofing should be provided above the footings. Where it is desired to prevent the passage of water, expansion joints and construction joints should be sealed by metal dams or other effective means.

Single-Span Arches and Box Culverts

2. Single-span arches and box culverts should be dampproofed on the surfaces in contact with the fill.

Pedestrian Subways

3. Pedestrian subways should be waterproofed.

Arches—Multiple Span with Spandrel Fill

4. Arches of multiple span with spandrel fill should be fully waterproofed on all surfaces in contact with the fill, including the parapets.

Precast Slabs for Bridge Decks and Floors

5. (A) Not over Streets or Pedestrian Subways—

(a) The top surface of slabs and the backs of parapets should be dampproofed when used on reinforced concrete pile bents with cast-in-place reinforced concrete caps, or on concrete piers.

(b) The top surface of slabs and the backs of parapets should be dampproofed when set on steel floorbeams, stringers or girders.

Joints should be calked with oakum up to within 2 or 3 inches of tops of slabs, the calking extending downward as far as necessary to close the joints against the flow of the waterproofing material used to fill the joints. The space above this oakum packing shall then be filled to the top surface of the slab with plastic joint-filling material.

(B) Over Streets or Pedestrian Subways—

In addition to treatment of joints as in paragraph (b) next above, the top surface of slabs and the backs of parapets should be waterproofed.

Cast-In-Place Concrete Bridge Decks or Floors

6. (a) The top surface of slabs and the backs of parapets should be dampproofed and the construction joints closed with metal dams, where the slab is an integral part of the structure, as in rigid frames or girderless flat slabs, or where it is the main load-carrying element, as in simple or continuous slabs, provided it is sufficiently reinforced for both positive and negative moments.

(b) When the slab is not a main load-carrying member, but is reinforced for temperature only and is supported on steel beams, all construction joints should be closed with metal dams and membrane waterproofing applied.

Pump Pits for Subways and Basements

7. Pump pits should be waterproofed or dampproofed on all exterior surfaces.

Pipe Manholes and Pipe Tunnels

8. Pipe manholes and pipe tunnels in water-bearing soils should be dampproofed or waterproofed on all exterior surfaces.

Water Containers

9. The walls and floors of water containers, such as reservoirs and tanks, should be made of dense concrete to insure watertightness. Special attention should be given to the waterproofing of all joints.

Walls and Floors of Buildings

10. The walls and floors of all buildings subject to hydrostatic pressure should be waterproofed on exterior and under surfaces.

If not subject to hydrostatic pressure, all exterior walls should be dampproofed. Special attention should be given to all joints and to places where pipes or other facilities pass through walls.

Grain Elevator Pits and Similar Underground Structures

11. Grain elevator pits and similar underground structures should be made watertight by design and construction or waterproofed on the exterior.

Appendix B

(4) SPECIFICATIONS FOR MEMBRANE WATERPROOFING

Scope

1. These specifications are intended to apply to materials and methods for waterproofing bridge decks, backs of abutments and retaining walls, tops and backs of culverts, subways, tunnels, conduits, foundations for buildings, walls and floors of basements and pits, tanks, reservoirs, dams and any other masonry structure or part of such structure, except roofs of buildings.

Design

2. Structures to be waterproofed shall be so designed that they can be waterproofed by the methods and with the materials specified herein. When the structure to be waterproofed is flexible and supported at intervals on comparatively rigid supports, such as cross girders in a viaduct, special care shall be taken to provide flexibility in the waterproofing membrane over such supports. Care shall also be taken to seal effectively or flash all places where the waterproofing membrane terminates, as along the webs of girders.

The waterproofing shall consist of a membrane covered by a protection of brick, concrete, mastic or other material.

Types

3. The membrane shall consist of one of the following types:
   (a) Two layers of bitumen-treated cotton fabric and three moppings of bitumen.
   (b) Three layers of bitumen-treated cotton fabric and four moppings of bitumen.
   (c) Two layers of bitumen-treated felt, one middle layer of bitumen-treated cotton fabric, and four moppings of bitumen.
   (d) Four layers of bitumen-treated felt, one middle layer of bitumen-treated cotton fabric, and six moppings of bitumen.

When greater strength is required, additional layers of bitumen-treated cotton fabric shall be applied.

MATERIALS

Bitumen

4. Bitumen shall consist of asphalt or coal-tar pitch. The mopped-on material shall be the same type of bitumen as that with which the felt or fabric is treated.

Asphalt for Saturant and Mopping Above Ground

5. Asphalt for saturant and mopping above ground shall be homogeneous and free from water. It shall be the product obtained by the distillation of crude asphaltic base petroleum with steam agitation, supplemented if necessary with oxidation by air, but without the addition, during any stage of the process of manufacture, of any fluxing material other than a native asphalt or a straight steam refined asphaltic residual. It shall meet the following requirements:

(a) Softening point (ring and ball method) ..... 150° to 170° Fahr. (65.5° to 76.7° C.)
(b) Penetration: at 115° Fahr. (46.1° C.), 50 g., 5 sec. ..... not more than 100
at 77° Fahr. (25° C.), 100 g., 5 sec. ..... 25 to 40
at 32° Fahr. (0° C.), 200 g., 60 sec. ..... not less than 10
(c) Flash point (open cup) ..... not less than 400° Fahr. (204.4° C.)
(d) Loss on heating at 325° Fahr. (163° C.), 50 g., 5 hr. ..... not more than 0.5 per cent
(e) Penetration at 77° Fahr. (25° C.), 100 g., 5 sec. of residue after heating at 325° Fahr. (163° C.), as compared with penetration of asphalt before heating ..... not less than 80 per cent
(f) Ductility: at 77° Fahr. (25° C.) elongated at rate of 5 cm. per min. ..... not less than 20 cm.
(g) Ductility: at 40° Fahr. (4° C.) elongated at rate of 1 cm. per min. ..... not less than 4 cm.
(h) Solubility in carbon disulphide ..... not less than 99 per cent

Asphalt for Mopping Below Ground

6. Asphalt for mopping below ground shall be either (a) a native refined asphalt fluxed with a petroleum flux, this flux to have a penetration at 77 degrees Fahr. of not less than 350 under a weight of 50 grams for one second; or (b) a petroleum asphalt obtained as a residue of an asphaltic petroleum by straight steam-refining without oxidation. It shall be free from admixtures of blown or oxidized residuals, cracked residuals, sludge asphalt, or their derivatives. It shall have the following properties:

	Fluxed Native Asphalt	*Petroleum Asphalt*
(a) Specific gravity at 60° Fahr.	1.04 to 1.07	1.03 to 1.06
(b) Penetration at 77° Fahr., 100 grams, 5 sec.	85 to 100	85 to 100
(c) Softening point (ring and ball method)	110° to 125° Fahr.	110° to 125° Fahr.

		Fluxed Native Asphalt	*Petroleum Asphalt*
(d)	Ductility of pure bitumen at 77° Fahr. (25° C.) elongated at rate of 5 cm. per min.	Min. 100 c.m.	Min. 100 c.m.
(e)	Flash point	350° Fahr. to 450° Fahr.	Min. 450° Fahr.
(f)	Loss on heating	Max. 2.0%	Max. 1.0%
(g)	Penetration at 77° Fahr., 100 g., 5 sec., of residue after heating at 325° Fahr. as compared with penetration of asphalt before heating	Min. 60%	Min. 60%
(h)	Pure bitumen soluble in carbon disulfide	Min. 95%	Min. 99½%
(i)	Inorganic matter, insoluble	Min. 1½%	...
(j)	Paraffine scale (Holde method)	Max. ½%	...

Coal-Tar Pitch for Saturant and Mopping

7. Coal-tar pitch for saturant and mopping shall be homogeneous and free from water. It shall meet the following requirements:

		For Use Above Ground	*For Use Below Ground*
(a)	Specific Gravity at 77°/77° Fahr. (25°/25° C.)	1.25 to 1.35	1.21 to 1.30
(b)	Softening point (cube in water method)	130° to 155° Fahr.	110° to 140° Fahr.
(c)	Distillation Test:		
	Total distillate by weight 32° to 572° Fahr. (0 to 300° C.)	Max. 10%	Max. 15%
	Residue by weight	Min. 90%	Min. 85%
(d)	Specific gravity, at 100°/77° Fahr. (38°/25° C.) of total distillate to 572° Fahr. (300° C.)	Min. 1.03	Min. 1.03
(e)	Ductility at 77° Fahr. (25° C.)	Min. 20 cm.	Min. 50 cm.
(f)	Solubility in carbon disulphide	63% to 78%	75% to 90%

Asphaltic Primer

8. Asphaltic primer shall be composed of asphalt that conforms to the foregoing requirements for asphalt for mopping below ground, and a solvent. It shall meet the following requirements:

(a)	Water	None
(b)	Asphaltic Base:	
	Per cent asphalt is of primer by weight	30 to 45
(c)	Solvent (Hydrocarbon distillate):	
	End point on distillation	Max. 500° Fahr. (260° C.)
	Per cent which shall distill under 248° Fahr. (120° C.)	Max. 20
(d)	Sediment	Max. 1%

Creosote Primer

9. Creosote primer for use with coal-tar pitch shall conform to the following requirements:

(a)	Water	Max. 2.0%
(b)	Consistency at 100° Fahr. (38° C.)	Entirely fluid
(c)	Specific gravity at 100°/77° Fahr. (38°/25° C.)	1.00 to 1.06
(d)	Insoluble in benzol	Max. 1.0%

(e) Distillation Test:
Total distillate, by weight, under 392° Fahr. (200° C.) ..... Max. 5.0%
Total distillate, by weight, under 455° Fahr. (235° C.) ..... Max. 50.0% Min. 30.0%
(f) Residue, by weight, above 671° Fahr. (355° C.) Max. 15.0%
(g) Specific gravity at 100°/77° Fahr. (38°/25° C.) of the fraction distilling between 455° and 599° Fahr. (235° C. and 315° C.)..... Min. 1.00
(h) Consistency at 77° Fahr. (25° C.) of the residue Soft

Fabric

10. Fabric shall consist of high-grade cotton cloth saturated thoroughly and uniformly with asphalt or coal-tar pitch for use above ground, which conforms to the foregoing specifications.

11. In the process of manufacture, the dry cotton fabric shall be treated thoroughly and uniformly at a temperature and speed that will not injure the fabric. This shall be accomplished by passing the fabric through the saturant and then calendering it in the presence of heat, after which it shall be cooled and wound into rolls.

Untreated Fabric

12. Untreated fabric shall contain no oil. It shall meet the following requirements:
(a) Thread count in either direction: Minimum 18; maximum 32.
(b) Average weight per square yard: For cloth having 18 to 24 thread count, not less than 5 ounces including not to exceed 6 per cent moisture regain; for cloth having 26 to 32 thread count, not less than 4 ounces including not to exceed 6 per cent moisture regain.
(c) Ash: Not more than one per cent of dry weight of fabric.

Treated Fabric

13. Treated fabric shall meet the following requirements:
(a) Width of roll: Minimum 30 in.; maximum 38 in.
(b) Gross weight of roll: Minimum 35 lb.; maximum 80 lb.
(c) Average weight per square yard: Not less than 11 ounces for 4 oz. cloth and 13¾ oz. for 5 oz. cloth.
(d) Moisture content: Not more than one per cent of net weight.
(e) Tensile strength at 70° Fahr. in either direction (grab method): Not less than 50 lb. per linear inch.
(f) Elongation without fracture: Not less than 10%.
(g) Pliability at 32° Fahr.: Not less than 10.
(h) Average loss on heating asphalt treated fabric (exclusive of moisture): Not more than 4 per cent.
(i) Weight of saturant in square yard of treated fabric: Not less than one and three-fourths times the weight of a square yard of untreated moisture-free fabric.

14. There shall be sufficient space between the threads of the untreated cotton fabric to allow the saturant to pass through. The surface of the saturated fabric shall be smooth and free from folds, knots and excess saturant.

Felt

15. Felt shall be rag-felt saturated, but not coated, with either asphalt or refined coal-tar; or asbestos felt saturated, but not coated, with asphalt. Rag felt shall be produced by felting vegetable and animal fibers.

16. Saturation shall be accomplished by passing the dry felt in single thickness through the saturant at a temperature and speed that will not injure the felt, and then calendering it between heated cylinders. It shall then be cooled and wound into rolls.

17. Rag felt shall meet the following requirements:

DESATURATED

		Asphalt Saturated	*Coal Tar Saturated*
(a)	Average weight of moisture-free felt	Min. 5.2 lb. per 100 sq. ft.	Min. 5.2 lb. per 100 sq. ft.
(b)	Ash in moisture-free felt	Max. 10%	Max. 10%

SATURATED

(a)	Width of roll	32 in. –36 in. ± ¼"	32 in. –36 in. ± ¼"
(b)	Gross weight of roll	40–80 lb.	40–80 lb.
(c)	Weight of material per 100 sq. ft. exclusive of wrapping and packing	14 lbs. ± 1 lb.	14 lbs. ± 1 lb.
(d)	Loss on heating at 221° Fahr. (105° C.) for 5 hrs.	Max. 4%	Max. 2½% of net weight
(e)	Moisture	.....	
(f)	Distillate, per cent by weight to 210° C. calculated on extracted saturant		Max. 2
	Distillate, per cent by weight to 235° C. calculated on extracted saturant		Max. 5
(g)	Pliability at 77° Fahr. (25° C.)	At least four strips out of five shall not crack when bent thru 180° over a $\frac{1}{16}$ in. mandrel	At least four strips out of five shall not crack when bent thru 180° over a $\frac{1}{16}$ in. mandrel
(h)	Saturant in moisture-free felt, by weight	Min. 140%	Min. 140%

18. Asbestos felt shall meet the following requirements:

DESATURATED

(a) Average thickness ..... not less than 0.045 in.
(b) The relative proportion of the organic and asbestos fibers based on a microscopic count:
  Organic ..... not more than 10%
  Asbestos and hair..... not less than 90%
(c) The felt shall contain cattle hair uniformly distributed. The amount of cattle hair shall be from 10 to 15 per cent, by weight, of the asbestos fiber content.

SATURATED

(a) Width of roll..... 32 to 36 in. ± ¼ in.
(b) Gross weight of roll..... 48–80 lb.
(c) Weight of material per 100 sq. ft. exclusive of wrapping and packing..... 30 lb. ± 1½ lb.
(d) Loss on heating at 221° Fahr. (105° C.) for 5 hrs..... not more than 4%
(e) Moisture content..... not more than ½% of net weight
(f) Weight of saturant, not less than 55% of the weight of moisture free felt.
(g) Mullen test to show a strength of 45 lb. minimum and 55 lb. maximum at 70° Fahr. (21° C.)

19. The surface of the felt shall be uniformly smooth, and upon splitting or tearing on the bias, shall appear reasonably free from lumps of underbeaten stock, i.e., stock

that has not been beaten or shredded into fiber in the process of manufacture, and from particles of foreign substance, such as fragments of stone, metal, leather, rubber, straw, wood, etc.

20. Felt shall be saturated thoroughly and uniformly and shall show no unsaturated spots at any point upon cutting 2-in. strips at random across the entire sheet and splitting them open for their full length.

21. Finished cotton fabric or felt shall be free from visible defects, such as holes, ragged or untrue edges, breaks, rents or cracks, and shall not be coated or covered with talc or other substance that will interfere with adhesion between the fabric or felt and the bitumen.

22. Saturated fabric shall be wound on mandrels not less than 2 in. in diameter and extending from 2 to 4 in. beyond the ends of the roll. Saturated felt need not be wound on cores.

23. Rolls of cotton fabric or felt shall be wrapped securely or tied to prevent unrolling in transit. It shall be of such quality that it may be unrolled easily at atmospheric temperatures above 50 degrees Fahr. without injury from sticking.

24. Cotton fabric, felt, asphalt and coal-tar pitch shall be delivered on the work in the original packages bearing the manufacturer's brand or label. The kind of material and the purpose for which it is to be used shall be indicated on the label.

Insulating Paper

25. Insulating paper shall be a waterproof paper 36 in. wide, weighing not less than 10 lb. per 100 sq. ft.

Plastic Cement

26. Plastic cement shall be composed of semi-solid asphalt dissolved in a suitable volatile solvent and stiffened with a mineral filler consisting essentially of short fiber asbestos.

27. The asphalt forming the base of plastic cement shall be either a fluxed native asphalt or a straight steam-refined asphaltic petroleum residual that has not been oxidized or blown, the pure bitumen of which shall meet the following minimum requirements:

Penetration at 77° Fahr., 100 grams, 5 sec.	30
Ductility at 77° Fahr., 5 c.m. per min.	100 c.m.

It shall be free from water, oxidized petroleum, residuals from the cracking process, sludge asphalt, tar or pitch products, or derivatives thereof.

28. Plastic cement shall meet the following requirements:

	By Weight
Fluxed Native or Steam-refined Petroleum Asphalt, not less than	38 per cent
Short Fiber Asbestos, not less than	25 " "
Petroleum Solvent, not more than	25 " "

29. Plastic cement shall be of such consistency that it can be spread readily with a trowel without drawing or pulling, or can be extruded through a suitable nozzle under a pressure of 50 lb. or more per sq. in.

30. When applied in a layer $\frac{1}{16}$ to $\frac{1}{8}$ in. thick, plastic cement shall set within 24 hours to a tough plastic coating, free from blisters.

31. After drying for 72 hours, a patch of plastic cement $\frac{1}{16}$ to $\frac{1}{8}$ in. thick, applied to the material upon which it is to be used, shall not blister or sag more than $\frac{1}{4}$ in. upon exposure at a temperature of 140 degrees Fahr. for five hours.

32. After drying for 72 hours, and exposure at a temperature of 140 degrees Fahr. for 5 hours, a patch of the cement $\frac{1}{16}$ to $\frac{1}{8}$ in. thick shall be plastic and adhere well to saturated fabric, saturated felt, metal or concrete, upon exposure at a temperature of 32 degrees Fahr. for one hour.

33. After drying for 24 hours and exposure at a temperature of 140 degrees Fahr. for 24 hours, and then cooling to a temperature of 70 to 77 degrees Fahr., a patch of the cement $\frac{1}{16}$ to $\frac{1}{8}$ in. thick shall not crack or break from the saturated fabric, saturated felt or metal, when bent over a mandrel 1 in. in diameter.

Asphalt Mastic

34. Asphalt mastic shall be used in the form of premoulded blocks or shall be poured in place. Poured-in-place mastic shall be composed of (a) asphalt mixed with mineral aggregates, or (b) mastic cake mixed with asphalt and mineral aggregates.

Asphalt for Mastic

35. Asphalt for mastic shall be homogeneous and free from water. It shall meet the following requirements:

Penetration: at 77° Fahr. (25° C.), 100 g., 5 sec.	25 to 30
Flash point (open cup)	not less than 347° Fahr. (175° C.)
Loss on heating at 325° Fahr. (163° C.), 50 g., 5 hr.	not more than 2 per cent
Penetration at 77° Fahr. (25° C.), 100 g., 5 sec. of residue after heating at 325° Fahr. (163° C.), as compared with penetration of asphalt before heating	not less than 60 per cent
Ductility at 77° Fahr. (25° C.)	not less than 15 cm.
Proportion of bitumen soluble in carbon tetrachloride	not less than 99 per cent

NOTE.—When less than 99 per cent of asphalt is soluble in carbon tetrachloride, the per cent of bitumen (solubility in carbon disulphide) shall be reported.

Coarse Mineral Aggregate

36. Coarse mineral aggregate shall be well-graded crushed stone or washed gravel that will pass a $\frac{3}{8}$-in. screen and be retained on a No. 10 screen. It shall be free from soft particles and organic matter.

Fine Mineral Aggregate

37. Fine mineral aggregate shall be well graded washed sand or crushed stone that will pass a No. 10 screen. It shall be free from soft particles and organic matter.

Mineral Filler

38. Mineral filler shall be finely ground limestone or silica meeting the following requirements:

Passing a 200-mesh sieve	not less than 75 per cent
Passing a 30-mesh sieve	not less than 100 per cent

Portland Cement

39. Portland cement shall meet the requirements of the Standard Specifications for Portland Cement of the American Railway Engineering Association, or current revisions thereof.

Mastic Cake

40. Mastic cake shall contain from 14 to 18 per cent, by weight, of matter soluble in pure benzol. The soluble matter shall be asphalt that will meet the requirements of

Section 35. The insoluble matter other than that inherently present in the asphalt used, shall be granular mineral matter that will meet the requirements of sections 37 and 38.

Premoulded Asphalt Blocks

41. Premoulded asphalt blocks shall meet the following requirements:

They shall be 4 in. wide, 8 in. long, and 1¼ in. thick. A deviation of ¼-in. in length or ⅛-in. in width or thickness either way from these dimensions, shall be cause for rejection.

The blocks shall be formed in moulds, under a pressure of not less than 3300 lb. per sq. in. of surface. An absorption test shall be made on blocks dried for 24 hours at a temperature of 150° Fahr. (65.5° C.) and then immersed in water seven days. The absorption of moisture under this test shall not exceed 1 per cent of the weight of the block.

Asphalt Plank

42. Asphalt plank shall be a mixture of asphalt, mineral matter and organic fiber, but not wood fiber. It shall be not less than 1¼-in. thick, and shall weigh not less than 85 lb. per cu. ft. The average of three tests shall show the following proportions by weight:

Asphalt (by Soxhlet extraction apparatus): Min. 40%; max. 48%; average 42.5%.
Mineral matter (measured as ash): between 35% and 45%.
Organic fiber, etc. (sum of asphalt and ash subtracted from 100): 8% to 22%.

The per cent of ash shall not exceed the percentage of asphalt.

43. From each shipment ten finished planks shall be selected at random, five for penetration and five for impact tests. One specimen shall be cut from each plank. If more than one specimen from each group fails to meet the requirements of the respective tests, the shipment will be rejected.

(a) The specimens for the penetration test shall be 6 in. by 6 in. They shall be kept at a temperature of 140 degrees Fahr. for 1½ hours immediately preceding the test. The test shall be made by placing the specimen under a freely moving plunger 1 in. in diameter, actuating a micrometer gage. The end of the plunger that is in contact with the specimen shall be convex with a radius of curvature of 2 in. A weight of 56 lb. shall be placed on the plunger and readings on the gage shall be taken 15 sec. and 75 sec. after the weight has been applied. The difference of these readings shall be the penetration of the specimen. To meet the requirements of this test, the penetration shall not exceed 0.03 in.

(b) The specimens for the impact test shall be 2 in. in diameter. They shall be kept at a temperature of 32 degrees Fahr. for 2 hours immediately preceding the test. The test shall be made by placing the specimen under a plunger 1 in. in diameter, which shall be seated exactly on center with the specimen. The end of the plunger that is in contact with the specimen shall be a plane surface perpendicular to the axis of the plunger. After the plunger is seated, a weight of 10 lb. shall be dropped on it from a height of 15 in. To meet the requirements of this test the specimen shall neither fracture nor crack.

44. The asphalt plank shall be of uniform width and thickness with sides straight and all edges square. The thickness, width and length, and details of bends shall be as shown on the plans. Curb and gutter plank shall be extruded in final shape from a mold. Irregularly formed planks shall be crated for shipment.

Asphalt plank shall be so loaded as to avoid deformation by irregular supports. The load shall be blocked, if necessary, to prevent shifting while in transit.

Materials for Concrete

45. Materials for concrete shall meet the requirements of the American Railway Engineering Association's current specifications for concrete. Reinforcing shall be steel wire netting with a mesh not less than 2 in. The wire shall be No. 14 gage or heavier.

Brick

46. Brick shall not be less than 2¼ in. thick with square corners, and shall be free from warp. It shall be dense, hard burned, and uniform in size and quality. The absorption of moisture by bricks immersed in water seven hours shall not exceed 10 per cent of the weight of the dry brick.

INSPECTION AND TESTS

47. Except as otherwise provided, materials shall be sampled and tested for the specified properties by the current methods recommended by the American Society for Testing Materials.

48. The acceptance of any materials by the Inspector shall not be a bar to their subsequent rejection if found defective. Rejected materials shall be replaced promptly by the manufacturer.

49. All materials to be furnished by the Contractor shall be delivered on the work not less than three weeks before they are to be applied, in order that they may be tested and analyzed. No materials shall be used until they have been accepted by the Engineer.

APPLICATION

50. Membrane waterproofing shall not be applied in wet weather, or when the atmospheric temperature is below 50 degrees Fahr. without written permission of the Engineer. The waterproofing shall be free from punctures, pockets or folds.

51. Surfaces to be waterproofed shall be dry and clean. Projections that might injure the membrane shall be removed. There shall be no depressions or pockets in horizontal surfaces of finished waterproofing. Concrete shall be well cured before waterproofing is applied.

52. The waterproofing shall be turned without break into drainage castings. Special care shall be taken to make the waterproofing effective along the sides and ends of girders and at stiffeners, gussets, etc. Grooves shall be filled with plastic cement specified in Sections 26 to 33, inclusive.

53. On surfaces that are vertical or nearly so, the strips of cotton fabric or felt shall be laid vertical or with the slope; on other surfaces the strips shall be laid shingle fashion, beginning at the lowest part of the surface to be waterproofed. Sufficient cotton fabric or felt shall be allowed for suitable lap or anchorage at the upper edge of the surface to be waterproofed.

54. Surfaces of concrete or steel coming in contact with asphalt waterproofing shall be given one coat of asphaltic primer before the first mopping of asphalt, or one coat of creosote primer before the first mopping of coal-tar pitch, except where insulation is to be used at expansion joints. The primer shall be well worked in to give a uniform coating. The priming coat shall be applied approximately 24 hours before applying the waterproofing membrane and shall be dry before the first mopping is applied.

55. Surfaces to be waterproofed shall be mopped in sections. While the first mopping of bitumen is still hot, a strip of cotton fabric or felt shall be laid on the mopping and pressed into place. Each mopping thereafter shall be so applied that it will com-

pletely cover and seal the cotton fabric or felt. The amount of bitumen used for each mopping shall be not less than 4½ gal. for each 100 sq. ft. of surface.

56. Asphalt shall not be heated above a temperature of 350 degrees Fahr., and coal-tar pitch not above 250 degrees Fahr. The bitumen shall be stirred frequently while being heated. Kettles shall be equipped with armored thermometers.

57. Two-ply work shall be started by mopping a section of the surface 2 in. wider than half the width of the cotton fabric or felt. On this hot mopping a half-width of the cotton fabric or felt shall be laid. The top surface of this cotton fabric or felt and an adjacent section of the surface 2 in. wider than a half-width of the cotton fabric or felt shall then be mopped. On this mopping shall be laid a full width of the cotton fabric or felt, completely covering the first strip. Thereafter full widths of cotton fabric or felt shall be laid in hot moppings, and in such manner that each strip will lap the second preceding strip by 2 in. Side laps shall be not less than 2 in. and end laps not less than 12 in.

58. The procedure for 3-ply work shall be the same as for 2-ply work, except that the first strip shall be a one-third width of the cotton fabric or felt; the second strip a two-thirds width; and the third and succeeding strips, full widths. The second full strip shall lap the first strip at least 2 in. Each succeeding strip shall lap the third preceding strip at least 2 in.

Membrane waterproofing consisting of more than three plies shall be built up in shingle fashion similar to 3-ply work by addition of as many plies as required.

59. The work shall be so regulated that at the end of the day all fabric or felt that has been laid will have received the final coat of bitumen.

60. Patching shall not be done without permission from the Engineer. Where patching is permitted for defective waterproofing it shall extend at least 12 in. beyond the outermost edge of the defective portion. The second and each succeeding ply of the patch shall extend at least 3 in. beyond the preceding ply.

61. At construction joints the primer shall be omitted for a width of 18 in. of the surface and a strip of insulating paper laid thereon before waterproofing is applied.

62. Expansion joints shall be filled with plastic cement conforming to these specifications. Joints shall be dry and clean immediately before they are filled. They shall be over-filled slightly to allow for shrinkage in drying.

Protective Cover

63. The protective cover shall be placed as soon as practicable after the membrane has been laid. Dirt and other foreign material shall be removed from the surface of the membrane immediately before the protective cover is placed. One of the following methods of protection shall be employed:

(a) A layer of poured-in-place asphalt mastic not less than 1½ in. thick.
(b) A layer of asphalt blocks not less than 1¼ in. thick or a layer of asphalt plank not less than 1¼ in. thick, laid in an extra heavy mopping of asphalt, with joints filled with hot asphalt.
(c) A layer of adequately reinforced cement mortar or concrete not less than 2 in. thick.
(d) A course of hard burned brick not less than 2¼ in. thick with joints filled with hot asphalt except that when laid as a vertical wall or on a steep slope, bricks shall be laid in cement mortar.

Note.—Mastic shall not be used on surfaces steeper than 4½ vertical to 12 horizontal. A protective cover containing asphalt shall be placed on only a membrane in which the bitumen used is asphalt.

64. Poured-in-place mastic shall be laid on one thickness of insulating paper placed on the membrane. It shall be made as specified in Sections 65 or 66.

65. The asphalt and mineral aggregates shall be mixed in the following proportions, varied within the specified limits, to give a mastic of the greatest density and stability:

Asphalt meeting requirements of section 35	9 to 12 per cent
Coarse mineral aggregate meeting requirements of section 36	33 to 40 per cent
Fine mineral aggregate meeting requirements of section 37	33 to 37 per cent
Mineral filler or Portland cement meeting requirements of sections 38 or 39	15 to 19 per cent

66. Mastic cake, asphalt and mineral aggregates shall be mixed in approximately the following proportions, varied to give a mastic of the greatest density and stability:

Mastic cake meeting requirements of section 40	48 per cent
Asphalt meeting requirements of section 35	5 per cent
Coarse mineral aggregate meeting requirements of section 36	28 per cent
Fine mineral aggregate, and mineral filler or Portland cement meeting requirements of sections 37 and 38 or 39	19 per cent

67. The asphalt and mastic cake shall be heated together to a temperature not above 350 degrees Fahr. The aggregates shall be mixed and heated and then placed in the kettle of melted asphalt. The ingredients shall be well-mixed with iron stirring rods until all pieces of the aggregate are covered with asphalt and the aggregates distributed uniformly throughout the mixture. During the mixing process care shall be taken to avoid burning the asphalt. After the mastic has been mixed it shall be poured into place while hot. It shall be placed in layers not more than ¾-in. thick. The thickness shall be gaged by wooden strips held in position by suitable weights. The layers shall be brought to the required thickness with wooden spreaders and floats, and shall lap joints not less than 6 in. The top layer shall be finished to the required grade and to a smooth surface. As soon as the top layer of the mastic is finished, it shall be given a mopping of hot asphalt sanded to a walking surface while hot.

68. Premoulded block protection shall be laid over the entire membrane except around drainage castings and other places shown on the plans. In such places, poured-in-place mastic or concrete shall be used. The blocks shall be laid in hot asphalt and the joints filled immediately with hot asphalt.

69. Asphalt plank protection shall be laid in hot asphalt. The asphalt shall be applied not less than 50 lb. to the square (100 sq. ft.) and the placing of the plank shall follow immediately. As successive planks are laid, the edges and ends of adjacent planks already laid shall be coated heavily with hot asphalt. The planks shall be laid tight against those previously laid so that the asphalt will completely fill the joints and be squeezed out at the top. After all planks have been laid, any joints not completely filled shall be filled with hot asphalt.

70. Concrete protection shall be not less than 2 in. thick and shall be reinforced as shown on the plans. The concrete shall be as dry as consistent with the workability required. It shall contain 1¾ barrels of cement per cubic yard of concrete.

71. Unless otherwise permitted by the Engineer, traffic shall not be allowed on the concrete until that deposited last has had the equivalent of seven days of good curing.

Brick Protection Course

72. Brick protection shall be laid over the entire membrane, except around drainage castings and at other places shown on the plans. In such places concrete shall be used. The joints between bricks shall be filled immediately after the bricks have been laid, with hot bitumen of the kind used for saturant and mopping, except that when against a vertical wall or on a steep slope the brick shall be laid in cement mortar.

REPORT OF COMMITTEE XVII—WOOD PRESERVATION

F. C. Shepherd, *Chairman;*
Wm. G. Atwood,
R. S. Belcher,
Z. M. Briggs,
Walter Buehler,
C. S. Burt,
G. B. Campbell,
H. R. Condon,
C. C. Cook,
G. M. Cornell,
E. A. Craft,
H. R. Duncan,
E. B. Fulks,
W. R. Goodwin,
C. W. Greene,
L. H. Harper,
L. B. Holt,
G. R. Hopkins,
H. E. Horrocks,
R. S. Hubley,
R. P. Hughes,
M. F. Jaeger,
F. C. Krell,
A. J. Loom,
C. F. Ford, *Vice-Chairman;*
G. P. MacLaren,
F. D. Mattos,
Clyde Osborne,
L. J. Reiser,
L. B. Shipley,
O. C. Steinmayer,
G. C. Stephenson,
T. H. Strate,
W. A. Summerhays,
C. M. Taylor,
Dr. H. von Schrenk,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully presents herewith reports covering the following subjects:

(1) Revision of Manual (Appendix A).

(2) Service Test Records for Treated Ties (Appendix B).

(3) Piling used for Marine Construction (Appendix C).

(4) Specifications for Treatment of Air-Seasoned Douglas fir, collaborating with Committees III—Ties and VII—Wooden Bridges and Trestles (Appendix D).

(5) Destruction by Termites and possible ways of Prevention (Appendix D).

(6) Loss of Preservative in Treated Ties in Track due to use of Oil-burning Weed Destroyers, collaborating with Committee XIII—Water Service and Sanitation, XXII—Economics of Railway Labor and XXVII—Maintenance of Work Equipment (Appendix F).

(7) Methods of Protection of Treated Materials in the Field, collaborating with Committees III—Ties and VII—Wooden Bridges and Trestles (Appendix G).

(8) Service Test Records of Structural Timber, including piling (Appendix H).

Action Recommended

1. That the information contained in Appendix A—Revision of Manual, Appendix D, Specifications for Treatment of Air-seasoned Douglas Fir, and the conclusions noted in Appendix H—Service Test Records of Structural Timber, be approved for publication in the Manual.

2. That the information contained in Appendix B—Service Test Records for Treated Ties; Appendix C—Piling Used in Marine Construction, and Appendix E—Destruction by Termite and possible ways of Prevention, be accepted as information.

3. That the information contained in Appendix F—Loss of Preservative in Treated Ties in Track due to repeated Use of Oil-burning Weed Destroyers, and Appendix H—Service Test Records of Structural Timber, including Piling, other than the conclusions reached, be accepted as information and the subjects discontinued.

4. That the information contained in Appendix G—Methods of Protection of Treated Materials in the Field—be received as information and the subject continued, with the recommendation to the Committee on Outline of Work that collaboration of Committees—III—Ties; VII—Wooden Bridges and Trestles, and XVII—Wood Preservation be directed with Committee XII—Rules and Organization to the end that approved rules be published in the Manual under the jurisdiction of Committee XII.

Respectfully submitted,

The Committee on Wood Preservation,

F. C. Shepherd, *Chairman.*

Bulletin 363, January, 1934.

Appendix A

(1) REVISION OF MANUAL

O. C. Steinmayer, Chairman, Sub-Committee; E. B. Fulks, R. S. Belcher, C. S. Burt, Walter Buehler, C. W. Greene, M. F. Jaeger, H. E. Horrocks, F. D. Mattos, G. C. Stephenson, L. B. Shipley, Dr. Hermann von Schrenk.

(A) PROPOSED SPECIFICATION FOR CREOSOTE

During recent years, committees representing the American Railway Engineering Association, the American Wood Preservers' Association and the American Society for Testing Materials, concerned with wood preservation, have been attempting to harmonize the creosote specifications of the various associations in order to eliminate a certain amount of confusion which has existed. This has been accomplished, practically, on the part of the American Wood Preservers' Association and the American Society for Testing Materials.

The present specifications of the American Wood Preservers' Association for Creosote and Creosote-Coal Tar Solution are very satisfactory, and are used very widely throughout the wood preserving industry. Your Committee believes that it would be advantageous to bring our specifications into harmony with those of the American Wood Preservers' Association. This will involve a change in the clauses relating to the specific gravity of fractions and the addition of two footnotes, and a renumbering of the various paragraphs.

The specific gravity requirements of the fractions 235–315°C. and 315–355°C. were inserted originally to prevent the addition to creosote of water-gas tar, but that situation no longer exists for the reason that water-gas tar has established a market for itself and is sold readily without resorting to subterfuge. On the other hand, changes have taken place in the production of coal tar which have changed the character of the tar itself. In the early days, the principal sources of coal tar were gas works or old-style coke ovens, both of which were operated at high temperatures and the tars produced were thick, viscous and of high specific gravity. Now, by far the larger proportion of tar comes from coke ovens which have been greatly improved in design, construction and method of operation and which produce thin tars having comparatively low specific gravities. This results in the production of considerable quantities of perfectly good coal-tar creosote which does not meet the requirements of 1.03 and 1.10 for specific gravity of fractions. We have collected the analyses of a great many creosotes which fall in this class and which represent a large volume of production. A few of them are presented as an illustration:

Specific Gravity at 38°C.

	Oil	*235/315*	*315/355*
A	1.058	1.028	1.092
B	1.086	1.027	1.093
C	1.064	1.028	1.092
D	1.055	1.026	1.090
E	1.075	1.022	1.097
F	1.065	1.024	1.091
G	1.059	1.030	1.096
H	1.079	1.030	1.095
I	1.082	1.028	1.100
J	1.053	1.025	1.088
K	1.061	1.026	1.100
L	1.065	1.029	1.099

The determining of the specific gravities of the fractions 235–315 and 315–355°C. has been found useful in connection with other analytical factors in determining whether the creosote is a pure coal tar product. In view of the changes in tar production, it is felt, however, that the figures now given in clause five of the present specification should be lowered. The specific gravity of the fraction between 235 and 315°C. is usually not lower than 1.025 and the specific gravity of the fraction between 315 and 355°C. is not usually lower than 1.085, both taken at 38°C. compared with water at 15.5°C. In their last revision of the creosote specification, the American Wood Preservers' Association, recognizing this fact, incorporated the clause just quoted as a part of a footnote. Your Committee feels that an identical footnote should be added to the revised specification for creosote oil which we are recommending.

In addition to this clause, your Committee also recommends that two other clauses adopted by the American Wood Preservers' Association as a part of the footnote dealing with two additional characteristics of the fractions of creosote be adopted by this Association in the identical form as that appearing in the American Wood Preservers' Association Manual.

Your Committee also recommends that a second footnote be appended to the revised American Railway Engineering Association specification similar to number two now part of the standard American Wood Preservers' Association specification. This deals with the interpretation of the clause dealing with the amount insoluble in benzol. Creosotes are frequently rejected because the quantity of insoluble is found to be slightly in excess of the specified quantity. It has been found that this is frequently due to the increase of insoluble matter due to treating operations.

The Manual now contains specifications for three grades of creosote which are of the same general character, the difference being that those for grades two and three provide for creosotes which are lighter and more volatile than grade one. These were written "to be used when the higher grade oil cannot be procured" and, presumably, these creosotes would be cheaper than grade one creosote. This situation no longer exists. There is now an ample supply of grade one creosote and only small quantities of grades two and three are manufactured. In fact, if a purchaser should desire to procure a large amount of either of these grades, he probably could not do so, or if he succeeded, it would be at a higher price than that of grade one. Since specifications for grades two and three no longer are pertinent, it would seem that they might well be discontinued. We are advised that the American Wood Preservers' Association is considering taking similar action.

The recommendations made with reference to changes in the present specification for grade one creosote are intended to apply equally to the present specification for 80/20 creosote coal tar solution.

Your Committee therefore recommends that the Manual be revised as follows:

1. Withdraw the specifications, shown on pages 1286, 1287 and 1288, Manual of 1929, for Creosote, Grade One; Creosote, Grade Two; Creosote, Grade Three; and Creosote-Coal Tar Solution.

2. Approve the following specifications for:

(A) Creosote—American Railway Engineering Association

STANDARD SPECIFICATIONS FOR CREOSOTE—GRADE ONE

1. The creosote shall be a distillate of coal-gas tar or coke-oven tar (see Note 1). It shall comply with the following requirements:

2. It shall not contain more than 3 per cent water.

3. It shall not contain more thon 0.5 per cent of matter insoluble in benzol (see Note 2).

4. The specific gravity of the creosote at 38°C., compared with water at 15.5°C. shall be not less than 1.03.

5. The distillate, based on water-free creosote, shall be within the following limits:

Up to 210°C. not more than 5 per cent.
Up to 235°C. not more than 25 per cent.

6. The residue above 355°C., if it exceeds 5 per cent, shall have a float test of not more than 50 seconds at 70°C.

7. The creosote shall yield not more than 2 per cent of coke residue.

8. The foregoing tests shall be made in accordance with the standard methods of the American Railway Engineering Association.

Notes

Note 1.—Owing to the complexity of the chemical composition and physical properties of coal-tar creosote, and to the fact that some of the same compounds and properties which characterize coal-tar creosote are found in certain petroleum derivatives, the determination of the purity of creosote is difficult. When there is not certain assurance that the creosote is a pure product, the following tests will aid in arriving at an opinion as to its coal-tar origin:

(a) Fraction distilling between 210°C. and 235°C. is usually solid or contains some solids when cooled to 25°C.

(b) All of the fractions up to 315°C. contain tar acids in varying amounts usually at least 1 per cent, calculated on the amount of the fraction tested.

(c) The specific gravity of the fraction between 235°C. and 315°C. is usually not lower than 1.025 and specific gravity of the fraction between 315° and 355° is usually not lower than 1.085 at 38°C. compared with water at 15.5°C. However, some pure coal-tar distillates fall slightly below these limits.

If the creosote does not comply with at least one of the foregoing tests, it is undoubtedly not a pure coal-tar creosote.

Note 2.—Samples of creosote taken from working tanks may show an increase in matter insoluble in benzol due to treating operations. Such increases, provided they do not exceed by 1 per cent the specification limits, should not serve to cause rejection of the creosote for non-conformity with specifications, if it can be shown that the original fresh creosote was of specified quality.

(B) Creosote Coal-Tar Solution—American Railway Engineering Association

STANDARD SPECIFICATIONS FOR CREOSOTE COAL-TAR SOLUTION

1. The solution shall be a coal-tar product of which at least 80 per cent shall be a distillate of coal-gas tar or coke-oven tar, and the remainder shall be refined or filtered coal-gas tar or coke-oven tar (see Note 1). It shall comply with the following requirements:

2. It shall not contain more than 3 per cent of water.

3. It shall not contain more than 2 per cent of matter insoluble in benzol (see Note 2).

4. The specific gravity of the solution at 38°C. compared with water at 15.5°C. shall be not less than 1.05 or more than 1.12.

5. The distillate, based on water-free creosote shall be within the following limits:

Up to 210°C. not more than 5 per cent
Up to 235°C. not more than 25 per cent

6. The residue above 355°C., if it exceeds 26 per cent shall have a float-test of not more than 50 seconds at 70°C.

7. The solution shall yield not more than 6 per cent coke residue.

8. The foregoing tests shall be made in accordance with the standard methods of the American Railway Engineering Association.

NOTES

NOTE 1.—Owing to the complexity of the chemical composition and physical properties of coal-tar creosote, and to the fact that some of the same compounds and properties which characterize coal-tar creosote are found in certain petroleum derivatives, the determination of the purity of creosote is difficult. When there is not certain assurance that the creosote is a pure product, the following tests will aid in arriving at an opinion as to its coal tar origin:

(a) Fraction distilling between 210°C. and 235°C. is usually solid or contains some solids when cooled to 25°C.

(b) All of the fractions up to 315°C. contain tar acids in varying amounts usually at least 1 per cent, calculated on the amount of the fraction tested.

(c) The specific gravity of the fraction between 235°C. and 315°C. is usually not lower than 1.025 and specific gravity of the fraction between 315° and 355° is usually not lower than 1.085 at 38°C. compared with water at 15.5°C. However, some pure coal tar distillates fall slightly below these limits.

If the creosote does not comply with at least one of the foregoing tests, it is undoubtedly not a pure coal-tar creosote.

NOTE 2.—Samples of solution taken from working tanks may show an increase in matter insoluble in benzol due to treating operations. Such increases provided they do not exceed by 1 per cent the specification limits, should not serve to cause rejection of the solution for non-conformity with specifications, if it can be shown the original fresh solution was of specified quality.

(C) STANDARD METHODS FOR THE DETERMINATION OF TAR ACIDS IN CREOSOTE

The American Railway Engineering Association, at the present time, has adopted methods for measuring, sampling and analyzing preservatives, which are printed in the Manual. There is one method, however, which has not yet been presented or recommended for adoption, namely the Standard Methods for Determination of Tar Acids in Creosote. Your Committee therefore presents such methods with the recommendation that they be approved as standard practice for inclusion in the Manual. The methods herewith recommended are the same as those included in the manual of recommended practices of the American Wood Preservers' Association. Both of these methods have been used and practiced for a great many years.

STANDARD METHODS FOR THE DETERMINATION OF TAR ACIDS IN CREOSOTE

Contraction Method

Apparatus.—Tar-acid separatory funnel, Type 1 (see Fig. 1). Tar-acid separatory funnel, Type 2 (see Fig. 2).

Distillation Method

Method.—100 c. c. of oil shall be placed in a distilling apparatus such as is used in distillation test and distilled until at least 95 per cent of distillate has been obtained or until the vapor temperature has reached 400°C. The entire distillate shall be transferred to a tar-acid separatory funnel, Type 1, designed for oils which have 25 per cent or over tar acids, or Type 2 for oils containing less than this amount. The funnel with the creosote shall be placed in a water bath and kept at a constant temperature of 60°C. until no change in volume takes place. It shall then be extracted with successive

portions of 50 c. c. each of 10 per cent caustic soda solution until no further diminution in volume occurs. The soda shall be added to the oil, the whole thoroughly shaken, then returned to the bath at 60°C. and allowed to settle completely. After settling is complete, the soda layer shall be drawn off and the volume of residual oil noted. When the point of no further contraction is reached, the diminution in volume of the oil shall be considered as tar acids.*

This test is recommended for all general work in oil specifications and general comparative tests, but gives results slightly higher than the true tar-acid content of the oil. The reason for this is that soda withdraws from creosote oil certain compounds which are not subsequently liberated from the soda solution in the form of an oil. These substances are evidently acid in nature but not phenolic bodies.

Liberation Method

Apparatus.—Same as above. Water and tar separatory funnel (see Fig. 2, J. Eng. and Ind. Chem. vol. 10 [1918], 735).

Method.—100 c. c. of oil shall be distilled as described above.

(Where the content of tar acids is very low, a distillation may be made on 200 c.c. so as to obtain a more accurate test.) The oil shall be shaken in a separatory funnel with successive 50 c.c. portions of 10 per cent caustic soda or until no more tar acids are removed. The well-settled separated carbolate shall be acidified in a small beaker with 40 per cent sulphuric acid, taking care to keep the mixture cool at all times. (If the content of tar acids is under 5 per cent, use the water in tar separatory funnel and measure carefully into it 10 c.c. of "Hiflash" naphtha. The liberated tar acids and sulphate solution are then poured through this layer of naphtha several times, drawing the material off at the bottom of the funnel into the original beaker and pouring it back into the top of the funnel. This washes out the beaker and allows all the tar acids to be absorbed by the naphtha.) The funnel shall then be allowed to stand until the layers separate perfectly clearly, when the sulphate solution shall be drawn off and the increase in volume of the naphtha taken as the dry tar acids present. When the content of acids is over 5 per cent the same procedure can be used, measuring 65 c.c. of "Hiflash" naphtha into the tar-acid separatory funnel, Type 2.

Precaution.—All results must be figured on the basis of dry oil.

Your Committee recommends the adoption of the above described Specification for Standard Methods for the Determination of Tar Acids in Creosote for publication in the Manual.

* In some cases (such as creosote-tar solutions containing small amounts of acids) there will be insufficient material to bring the oil up into the graduated section of Type 2 separatory funnel. In such cases, sufficient tar-acid free, clean, heavy naphtha may be added to dilute the oil and bring it within the graduated portion.

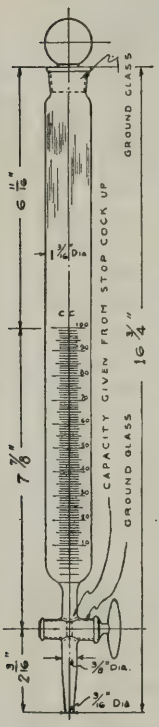

Fig. 1—Tar-Acid Separatory Funnel, Type 1.

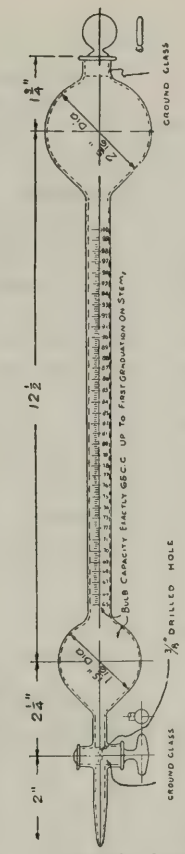

Fig. 2—Tar-Acid Separatory Funnel, Type 2.

Appendix B

(2) SERVICE TEST RECORDS FOR TREATED TIES

W. R. Goodwin, Chairman, Sub-Committee; Z. M. Briggs, C. S. Burt, E. A. Craft, C. W. Greene, L. B. Holt, R. S. Hubley, R. P. Hughes, A. J. Loom, F. C. Krell, G. P. MacLaren, T. H. Strate.

The table of tie renewals per miles maintained on the various railroads has been revised to include renewals for 1932.

Reports are submitted covering special test tracks on the following lines:

Chicago, Burlington & Quincy.
St. Louis Southwestern.
Chicago and Northwestern.
Chicago, Milwaukee, & St. Paul.
Atchison, Topeka, and Santa Fe.

Conclusion

Your Committee recommends that this report be accepted as information.

CHICAGO, BURLINGTON & QUINCY RAILROAD
REPORT ON SPECIAL TEST TRACKS—SUMMARY OF 1932 INSPECTION
RESULTS OF 23 YEARS' SERVICE

Process	LINES EAST					LINES WEST				
	Total Placed	Total Removed to date	% removed account decay	% removed account other causes	Actual Average Year's Life to date	Total Placed	Total Removed to date	% removed account decay	% removed account other causes	Actual Average Year's Life To date
Straight Creosote	2,046	830	13	28	20.2	1,236	622	14	36	19.6
Card Process	10,242	7,343	25	47	17.5	5,591	4,515	30	51	17.0
Burnettizing	1,578	1,394	47%	42	15.1	910	870	46	49	14.7
Untreated	2,046	2,039	89	10	5.5	1,226	1,225	91	9	5.8
Total Treated	13,866	9,567	26	43	17.6	7,737	6,007	29	48	17.1
Grand Total	15,912	11,606	34	39	16.0	8,963	7,232	38	43	15.6

NOTE: We have included in these percentages only the ties placed in what we term the thousand tie lots on the various divisions.

ASH TIES

Process	LINES EAST					LINES WEST				
	Total Placed	Total removed to date	% removed account decay	% removed account other causes	Actual Average year's life to date	Total Placed	Total removed to date	% removed account decay	% removed account other causes	Actual average year's life to date
Straight Creosote	19	16	25	58	15.3	15	10	20	47	19.4
Card Process	289	216	15	60	17.4	103	82	19	60	17.4
Burnettizing	16	12	31	44	17.1	15	14	40	53	17.1
Untreated	70	70	99	1	5.1	46	46	100	0	5.2
BEECH TIES										
Straight Creosote	321	71	6	17	21.5	163	47	7	22	21.5
Card Process	807	671	38	45	16.6	418	359	38	48	16.7
Burnettizing	210	185	48	40	14.8	105	99	54	40	15.6
Untreated	134	134	98	2	4.8	74	74	93	7	5.4
BIRCH TIES										
Straight Creosote	75	37	36	13	20.1	59	25	14	29	19.0
Card Process	715	517	30	42	16.5	360	302	32	52	17.4
Burnettizing	73	73	48	52	11.9	30	30	47	53	14.4
Untreated	139	139	99	1	3.9	78	78	100	0	3.8
CHESTNUT TIES										
Straight Creosote	0	0	0	0	0	0	0	0	0	0
Card Process	164	161	16	82	10.0	89	89	9	91	10.2
Burnettizing	0	0	0	0	0	0	0	0	0	0
Untreated	169	167	27	72	9.4	90	90	22	78	10.2
COTTONWOOD TIES										
Straight Creosote	88	27	1	30	20.8	45	14	11	20	20.1
Card Process	296	205	22	47	17.9	160	124	23	54	16.9
Burnettizing	0	0	0	0	0	0	0	0	0	0
Untreated	56	56	95	5	2.6	30	30	100	0	3.5

Chicago, Burlington & Quincy Railroad (Continued)

CYPRESS TIES

Process	LINES EAST: Total Placed	Total removed to date	% removed account decay	% Removed account other causes	Actual Average year's life to date	LINES WEST: Total Placed	Total removed to date	% removed account decay	% removed account other causes	Actual average year's life to date
Straight Creosote	25	5	0	20	21.0	29	21	41	31	19.0
Card Process	409	291	9	62	18.2	254	204	24	56	17.5
Burnettizing	25	15	0	60	19.5	30	30	50	50	14.7
Untreated	135	132	78	20	8.8	90	90	89	11	7.4
ELM TIES										
Straight Creosote	208	69	13	20	20.6	119	40	8	25	20.8
Card Process	594	349	20	39	19.0	371	246	26	41	19.0
Burnettizing	224	176	34	44	17.4	73	66	56	34	15.8
Untreated	113	113	91	9	5.0	78	78	96	4	5.9
HEMLOCK TIES										
Straight Creosote	136	92	24	43	18.1	99	78	21	58	17.8
Card Process	816	631	25	53	17.0	488	439	37	53	15.4
Burnettizing	125	107	42	43	16.4	87	79	33	57	15.2
Untreated	112	112	100	0	4.9	78	78	99	1	5.2
HICKORY TIES										
Straight Creosote	10	2	10	10	20.8	15	7	13	33	19.8
Card Process	185	173	38	54	15.9	105	95	41	50	15.6
Burnettizing	9	6	0	67	19.3	15	15	53	47	17.3
Untreated	65	65	89	11	5.6	45	45	100	0	5.5
PINE TIES - LOBLOLLY SAP										
Straight Creosote	145	56	3	35	20.5	72	50	18	51	17.0
Card Process	949	623	24	42	17.4	386	320	24	59	14.9
Burnettizing	128	126	73	26	11.9	72	72	46	54	12.0
Untreated	157	157	99	1	5.8	91	91	100	0	4.8

HARD MAPLE TIES

Process	LINES EAST: Total Placed	Total removed to date	% Removed account decay	% Removed account other causes	Actual average year's life to date	LINES WEST: Total Placed	Total removed to date	% removed account decay	% removed account other causes	Actual average year's life to date
Straight Creosote	82	28	23	11	20.8	34	18	8	44	20.2
Card Process	561	349	28	35	18.6	272	217	32	48	18.4
Burnettizing	50	40	36	44	18.0	15	15	87	13	15.7
Untreated	77	76	97	1	4.3	45	45	100	0	5.3
SOFT MAPLE TIES										
Straight Creosote	139	99	33	38	18.0	53	30	21	27	19.3
Card Process	462	374	43	38	16.0	264	190	22	50	17.7
Burnettizing	125	124	63	36	13.0	57	56	37	61	13.2
Untreated	82	82	99	1	3.4	43	43	95	5	4.0
WHITE OAK TIES										
Straight Creosote	25	2	0	8	21.6	15	11	27	47	18.7
Card Process	234	210	36	53	16.5	152	132	29	58	16.6
Burnettizing	28	26	54	39	16.3	15	15	40	60	15.2
Untreated	81	81	88	12	10.8	44	43	80	18	11.7
RED OAK TIES										
Straight Creosote	165	52	2	30	21.0	120	60	13	37	20.3
Card Process	776	508	18	48	18.4	510	465	32	59	17.0
Burnettizing	158	134	43	42	16.5	116	108	41	53	15.1
Untreated	129	129	96	4	5.1	75	75	93	7	5.7
PIN OAK TIES										
Straight Creosote	189	52	3	24	21.5	133	37	7	21	21.5
Card Process	512	287	14	42	19.6	321	241	24	51	18.9
Burnettizing	23	11	13	35	19.7	44	43	32	66	14.0
Untreated	81	80	96	4	6.4	45	45	98	2	6.2

Chicago, Burlington & Quincy Railroad (Continued)

Process	LINES EAST: Total Placed	Total removed to date	% Removed account decay	% Removed account other causes	Actual average year's life to date	LINES WEST: Total Placed	Total removed to date	% Removed account decay	% Removed account other causes	Actual average year's life to date
POPLAR TIES										
Straight Creosote	50	21	8	34	19.9	30	27	17	73	16.8
Card Process	396	346	37	51	15.0	253	220	38	49	15.0
Burnettizing	50	47	40	54	13.2	30	30	57	43	13.0
Untreated	81	81	94	6	5.1	45	45	96	4	5.6
RED GUM TIES										
Straight Creosote	89	53	25	35	18.7	46	31	27	38	17.0
Card Process	429	292	29	39	18.0	253	155	35	32	18.3
Burnettizing	75	73	64	33	11.5	43	41	70	26	12.3
Untreated	98	98	97	3	3.8	54	54	98	2	4.6
SYCAMORE TIES										
Straight Creosote	75	27	21	15	19.8	15	2	0	13	22.0
Card Process	399	229	35	22	17.3	121	109	62	28	14.3
Burnettizing	75	73	69	28	11.3	15	15	80	20	13.5
Untreated	81	81	98	2	2.9	50	50	96	4	3.9
TAMARACK TIES										
Straight Creosote	106	59	8	58	19.8	108	83	14	63	17.9
Card Process	813	697	19	67	17.2	494	439	31	58	16.8
Burnettizing	108	93	32	54	17.5	107	101	30	65	16.0
Untreated	98	98	96	4	4.9	77	77	99	1	5.3
TUPELO GUM TIES										
Straight Creosote	99	52	19	33	19.8	54	31	20	37	18.4
Card Process	436	214	13	36	19.7	237	87	17	20	21.1
Burnettizing	76	73	45	51	15.1	41	41	61	39	14.0
Untreated	88	88	98	2	3.0	48	48	98	2	4.4

ST. LOUIS SOUTHWESTERN RAILWAY LINES

Experimental cross ties installed South of Texarkana, Texas

Conditions as found on annual inspection made on October 4, 1932

Previously reported in 1931 Proceedings

Kind	Treatment	Number Installed	Date Installed	Condition on October 4th, 1932: Remaining in track: Number	Per cent	Average life in Yrs
Mixed green and seasoned Loblolly and short leaf pine	12 lbs. creosote per cu .ft	1154	July 1910	319	27.7	16.8
Mixed green and seasoned long leaf southern pine	12 lbs creosote per cu.ft	600	July 1910	395	65.8	20.0
Red Oak	7 lbs creosote per cu ft	400	200 in July 1910 200 in Dec 1911	95	23.7	17.2
White Oak	7 lbs. creosote per cu.ft	200	July 1910	5	2.5	14.2
Loblolly and short leaf pine	Allardyce	200	Dec 1911	39	19.5	14.4
All test ties	Various	2554	July 1910 Dec 1911	853	33.4	17.1

[1]Rail cutting, splitting, etc. *Dry zinc chloride. [a]Estimated [b]Actual

CROSS TIE RENEWALS PER MILE OF ALL TRACK MAINTAINED · 1911 - 1940

[illegible]	B & O	B & O	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	GT. NORTHERN	ILL. CENTRAL	K C SOU	LEHIGH VALLEY	MICH CENT	M K & T	MONON [illegible]	N Y C EAST	N Y C WEST	NOR PACIFIC	PENNA	SOO LINE	SOUTHERN PAC (ATLANTIC SYST.)	SOUTHERN PAC (PACIFIC SYST.)	UNION PACIFIC	C P R [illegible]	READING	BOSTON & MAINE	C & O	TOTALS FOR ALL ROADS

Ⓢ [illegible]

Condition of experimental ties in the Chicago and Northwestern Railway test track near Janesville, Wis., after about 25-1/2 years service.

Preservative	Process	Average absorption	Ties in test	Splitting[1] No.	Splitting[1] Per cent	Decaying No.	Decaying Per cent	Removed: Mainly for decay No.	Removed: Mainly for decay Per cent	Removed: For causes other than decay[1] and unknown causes No.	Removed: For causes other than decay[1] and unknown causes Per cent	Average life
		Lbs. per cu. ft.	No.									Years
Hemlock												
Zinc chloride	Burnett	.26*	25	--	--	3	12.0	18	72.0	4	16.0	17.7[a]
Zinc chloride - glue and tannin	Wellhouse	.47*	1530	2	0.1	383	25.0	990	64.7	155	10.2	21.3[a]
Creosote	Open tank	5.36	33	--	--	4	12.1	25	75.7	4	12.2	19.2[a]
Untreated	--	--	169	--	--	--	--	169	100.0	--	--	6.5[b]
Tamarack												
Zinc chloride	Burnett	.50*	388	1	0.3	89	22.9	243	62.6	55	14.2	22.2[a]
Zinc chloride - glue and tannin	Wellhouse	.42*	738	--	--	131	17.7	528	71.6	79	10.7	21.1[a]
Creosote	Open tank	5.74	19	--	--	9	47.4	10	52.6	--	--	24.3[a]
Untreated	--	--	125	--	--	--	--	125	100.0	--	--	6.2[b]
White Oak												
Untreated	--	--	50	--	--	--	--	50	100.0	--	--	10.1[b]
Summary by treatments (Irrespective of species)												
Zinc chloride	Burnett	--	413	1	0.2	92	22.3	261	63.2	59	14.3	21.9[a]
Zinc chloride - glue and tannin	Wellhouse	--	2268	2	0.1	514	22.6	1518	67.0	234	10.3	21.3[a]
Creosote	Open tank	--	52	--	--	13	25.0	35	67.4	4	7.6	21.1[a]

[1] Rail cutting, splitting, etc. *Dry zinc chloride. [a] Estimated [b] Actual

Condition of experimental ties in the Chicago, Milwaukee, St Paul and Pacific Railway test track near the Fair Grounds, Madison, Wisconsin.

Results of October 1933 inspection

Species	Preservative	Average absorption of oil or dry salt	Ties in test	Years service	Good		Splitting		Decaying		Removed: Mainly for decay		Removed: For causes[a] other than decay	
					No.	Per cent	No.	Per cent	No.	Per cent	No.	Per cent	No	Per cent
		Lbs. per cu. ft.	No.	No.										
Douglas fir[b]	Creosote	11.50	29	16	27	93.1	2	6.9	--	--	--	--	--	--
Red oak	Zinc chloride	0.55	185	17	2	1.1	3	1.6	97	52.4	78	42	2	2.7
Red oak	25% creo. and 75% gas oil	10.20	99	17	32	32.3	53	53.6	12	12.1	2	2.0	--	--
Red oak	10% creo. and 90% gas oil	10.00	98	17	39	39.8	41	41.9	16	16.3	1	1.0	1	1.0
Douglas fir[b]	Untreated[c]	--	38	--[c]	--	--	--	--	--	--	36	94.7	2	5.3
White oak	Untreated	--	95	16	--	--	--	--	7	7.4	87	91.5	1	1.1
Red oak	Sodium fluoride	0.52	99	16	2	2.0	2	2.0	87	87.9	8	8.1	--	--
Red oak	Water gas tar	9.79	100	16	51	51.0	49	49.0	--	--	--	--	--	--
Western larch	Untreated	--	44	16	--	--	--	--	2	4.5	41	93.2	1	2.3
Douglas fir[b]	Untreated	--	48	16	4	8.3	2	4.2	7	14.6	32	66.7	3	6.2
Douglas fir[b]	Zinc chloride	0.52	105	14	7	6.7	18	17.1	53	50.5	18	17.1	9	8.6
Western larch	Zinc chloride	0.48	95	14	22	23.2	13	13.7	33	34.7	13	13.7	14	14.7
Red oak	50% C.T.creo. & 50% W.T.creo.	9.50	62	14	39	62.9	21	33.9	1	1.6	--	--	1	1.6
Slippery elm	50% C.T.creo. & 50% W.T.creo.	10.85	25	14	4	16.0	20	80.0	1	4.0	--	--	--	--
Butternut	50% C.T.creo. & 50% W.T.creo.	9.00	9	14	--	--	6	66.7	3	33.3	--	--	--	--
White oak	50% C.T.creo. & 50% W.T.creo.	7.30	1	14	1	100.0	--	--	--	--	--	--	--	--
Cherry	50% C.T.creo. & 50% W.T.creo.	10.50	3	14	1	33.3	2	66.7	--	--	--	--	--	--
Red oak	Wood tar creosote	10.08	100	14	32	32.0	38	38.0	20	20.0	2	2.0	8	8.0
Red oak	Low temperature coal tar oil	10.30	100	12	49	49.0	51	51.0	--	--	--	--	--	--
Red oak	50% tar and 50% low temp. coal tar oil	10.50	100	12	52	52.0	48	48.0	--	--	--	--	--	--
Red oak	Vertical retort C.T.creo.	9.60	100	12	68	68.0	32	32.0	--	--	--	--	--	--
Red oak	Pintsch gas tar	10.50	100	12	59	59.0	41	41.0	--	--	--	--	--	--
Jack pine	Zinc chloride	0.52	381	6	374	98.2	6	1.6	1	0.2	--	--	--	--

[a] Rail cutting, splitting, etc. [b] Western Washington and Oregon type. [c] Switch ties - average life 6.5 years.

Condition of experimental ties in the Chicago, Milwaukee, St Paul and Pacific Railway test track near Hartford, Wis., after about 21-3/4 years service

Ties set October 1911										Ties inspected June 1933			
Preservative	Process	Tie plates	Average absorption	Ties in test	Good		Splitting		Decaying	Removed: Mainly for decay		Removed: For causes[a] other than decay and unknown causes	
					No.	Per cent	No.	Per cent	No. Per cent	No.	Per cent	No.	Per cent
			Lbs. per cu. ft.	No.									
Chestnut													
Zinc chloride	Burnett[b]	Flat	12.5[c]	10	--	--	--	--	1:10.0	8	80.0	1	10.0
Zinc chloride	Burnett[b]	Ribbed	12.5[c]	13	--	--	--	--	1: 7.7	7	53.8	5	38.5
Maple													
Creosote	Full cell	None	10.7	50	6	12.0	34	68.0	10:20.0	--	--	--	--
Creosote	Full cell	Flat	12.2	49	9	18.4	37	75.5	3: 6.1	--	--	--	--
Creosote	Rueping	Flat	5.0	50	9	18.0	34	68.0	7:14.0	--	--	--	--
Creosote	Rueping	None	4.8	50	5	10.0	40	80.0	5:10.0	--	--	--	--
20% creo., 80% zinc chloride	Card	None	14.7[d]	50	7	14.0	29	58.0	12:24.0	1	2.0	1	2.0
20% creo., 80% zinc chloride	Card	Flat	17.3[d]	50	1	2.0	30	60.0	17:34.0	2	4.0	--	--
Semi-refined paraffin oil	Full cell	Flat	11.1	50	--	--	32	64.0	13:26.0	3	6.0	2	4.0
Semi-refined paraffin oil	Full cell	None	14.3	49	--	--	38	77.6	10:20.4	1	2.0	--	--
Zinc chloride-creosote	Two movement	Flat	16.4[e]	50	3	6.0	24	48.0	20:40.0	3	6.0	--	--
Zinc chloride-creosote	Two movement	None	15.1[e]	50	3	6.0	12	24.0	20:40.0	15	30.0	--	--
Zinc chloride	Burnett	None	20.1[f]	49	--	--	--	--	13:26.6	25	51.0	11	22.4
Zinc chloride	Burnett	Flat	20.1[f]	50	--	--	--	--	32:64.0	16	32.0	2	4.0
Untreated[1]	--	None	--	50	--	--	--	--	--: --	50	100.0	--	--
Untreated[2]	--	Flat	--	50	--	--	--	--	--: --	50	100.0	--	--

[a] Rail cutting, splitting, etc

[b] Obtained from regular stock of C.M.St.P. & P. Ry.,

[c] 4% zinc chloride solution.

[d] Emulsion of 80 parts of 3% zinc chloride solution and 20 parts of creosote by volume at approximately 70°F.

[e] 3% zinc chloride solution plus creosote. Treatment consisted of bath in hot creosote for 30 minutes at atmospheric pressure followed by pressure treatment with 3% zinc chloride solution.

[f] 2½% zinc chloride solution

[1] Average life 6.4 years

[2] Average life 7.8 years

Condition of experimental ties in the Chicago, Milwaukee, St. Paul and Pacific Railway test track near Hartford, Wis., after about 21-3/4 years service (Continued)

Ties set October 1911					Ties inspected June 1933										
											Removed				
Preservative	Process	Tie plates	Average absorption	Ties in test	Good		Splitting		Decaying		Mainly for decay		For causes[a] other than decay and unknown causes		
					No.	Per cent	No.	Per cent	No.	Per cent	No.	Per cent	No	Per cent
			Lbs. per cu. ft.	No.										
Red Oak															
Creosote	Full cell	None	11.2	52	27	51.9	24	46.2	--	--	--	--	1	1.9
Creosote	Full cell	Flat	10.9	50	23	46.0	25	50.0	1	2.0	--	--	1	2.0
Creosote	Rueping	Flat	5.0	50	21	42.0	20	40.0	8	16.0	1	2.0	--	--
Creosote	Rueping	None	5.7	50	12	24.0	33	66.0	2	4.0	2	4.0	1	2.0
20% creo.,80% zinc chloride	Card	None	15.5[d]	50	9	18.0	16	32.0	22	44.0	1	2.0	2	4.0
20% creo.,80% zinc chloride	Card	Flat	15.2[d]	50	13	26.0	8	16.0	29	58.0	--	--	--	--
Semi-refined paraffin oil	Full cell	Flat	8.4	50	5	10.0	7	14.0	37	74.0	1	2.0	--	--
Semi-refined paraffin oil	Full cell	None	6.2	49	2	4.1	12	24.5	32	65.3	2	4.1	1	2.0
Zinc chloride-creosote	Two movement	Flat	14.7[e]	50	11	22.0	12	24.0	24	48.0	3	6.0	--	--
Zinc chloride-creosote	Two movement	None	16.0[e]	50	4	8.0	11	22.0	29	58.0	3	6.0	3	6.0
Zinc chloride	Burnett[b]	Flat	12.5[c]	157	--	--	--	--	41	26.1	103	65.6	13	8.3
Zinc chloride	Burnett[b]	Flat	12.5[c]	49	--	--	--	--	17	34.7	30	61.2	2	4.1
Zinc chloride	Burnett[b]	Ribbed	12.5[c]	53	--	--	--	--	24	45.3	26	49.0	3	5.7
Zinc chloride	Burnett	None	15.8[g]	50	--	--	--	--	38	76.0	11	22.0	1	2.0
Zinc chloride	Burnett	Flat	16.4[g]	50	--	--	--	--	42	84.0	6	12.0	2	4.0
Untreated[3]	--	None	--	50	--	--	--	--	--	--	50	100.0	--	--
Untreated[4]	--	Flat	--	50	--	--	--	--	--	--	50	100.0	--	--
Spruce															
Mercuric chloride	Kyan	Flat	[h]	13	--	--	3	23.1	6	46.1	4	30.8	--	--
Mercuric chloride	Kyan	None	[h]	12	--	--	1	8.3	4	33.4	6	50.0	1	8.3

[a] Rail cutting, splitting, etc.

[b] Obtained from regular stock of C.M.St. P. & P. Ry.

[c] 4% zinc chloride solution

[d] Emulsion of 80 parts of 3% zinc chloride solution and 20 parts of creosote by volume at approximately 70°F.

[e] 3% zinc chloride solution plus creosote. Treatment consisted of bath in hot creosote for 30 minutes at atmospheric pressure followed by pressure treatment with 3% zinc chloride solution.

[g] 3% zinc chloride solution

[h] Steeping treatment in cold mercuric chloride solution. Absorption figures not available.

[3] Average life 8.7 years.

[4] Average life 9.2 years.

STATEMENT SHOWING VARIOUS SPECIAL TESTS FOR THE AMERICAN RAILWAY ENGINEERING ASSOCIATION
AS OF DECEMBER 31, 1932
A. T. & S. F. RY.

Station	Year Insert-ed.	Original Number Inserted	Total Ties Removed	% Ties Removed From Track	Average Life to 12-31-32
HEWN SOUTHERN YELLOW PINE ZINC CHLORIDE					
Newton, Kansas, EB	1904	6357	6354	99.95	13.25
Newton, Kansas, EB	1905	9251	9178	99.21	13.47
Turner-Holliday, Kans.	1918	4638	3020	66.83	11.62
SAWN SOUTHERN YELLOW PINE ZINC CHLORIDE					
Newton, Kansas, EB	1904	2517	2496	99.17	13.49
Newton, Kansas, EB	1905	40	40	100.00	12.87
Turner,Holliday, Kans.	1918	673	427	63.45	11.20
HEWN SOUTHERN YELLOW PINE CREOSOTE					
Clements, Kansas	1904	165	158	95.76	19.53
Ponca City, Okla.	1904	190	129	67.89	23.31
Perry, Okla.	1904	27	25	88.89	22.81
Marceline, Mo.	1905	304	304	100.00	14.55
Melvern, Kans.	1906	24224	14108	58.24	22.88
Mission-Hutchinson, Kans.	1909	106	2	1.89	22.90
St. John-Sylvia, Kans.	1910	41011	2578	6.29	21.74
Lewis, Kansas	1910	13642	1243	9.11	21.70
Justiceburg, Texas,	1911	1460	565	39.93	19.39
Newton, Kansas, EB	1913	149	28	18.79	18.89
Texico-Lubbock, Texas	1913	100641	12805	12.72	18.62
Walton, Kansas	1917	10848	317	2.83	14.84
Turner-Holliday, Kansas	1918	5836	826	14.15	13.54
Chilocco, Okla.	1919	10268	1499	14.60	12.34
Chilocco, Okla.	1919	3262	44	1.35	12.97
SAWN SOUTHERN YELLOW PINE CREOSOTE					
Marland, Okla.	1904	275	255	92.73	21.20
Perry, Okla.	1904	348	272	78.16	22.04
Garnett, Kans.	1905	383	300	78.33	19.08
Argonia, Kansas	1905	572	523	91.43	16.45
Mission-Hutchinson, Kans.	1909	69	26	37.68	19.61
St. John-Sylvia, Kans.	1910	9564	3802	39.75	19.68
Texico-Lubbock, Tex.	1913	162011	18977	11.71	18.67
Newton, Kansas, EB	1913	151	10	6.62	18.89
Walton, Kansas	1917	1362	33	3.37	14.64
Turner-Holliday, Kans.	1918	978	126	12.88	13.58

Sheet # 2

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Station	Year Insert-ed.	Original Number Inserted	Total Ties Removed	% Ties Removed From Track	Average Life to 12-31-32
SAWN SOUTHERN YELLOW SAP PINE CREOSOTE					
Justiceburg, Texas	1911	376	279	74.20	15.99
SAWN SOUTHERN YELLOW HEART PINE CREOSOTE					
Justiceburg, Texas	1911	374	23	6.15	20.76
HEWN WHITE OAK CREOSOTE					
Justiceburg, Texas	1911	375	84	22.40	20.07
HEWN RED OAK CREOSOTE					
Justiceburg, Texas	1911	225	44	19.56	20.17
Texico-Lubbock, Tex.	1913	171	24	14.04	18.61
Newton, Kansas	1913	150	1	0.67	18.92
Walton, Kansas	1917	4348	114	2.62	14.88
Turner-Holliday, Ka.	1918	2763	31	1.12	13.97
SAWN RED OAK CREOSOTE					
Plevna, Kansas	1907	52	47	90.38	15.62
Justiceburg, Texas	1911	281	84	29.89	18.43
HEWN GUM CREOSOTE					
St. John-Sylvia, Ka.	1909	1330	20	1.50	22.95
St. John-Sylvia, Ka.	1910	13076	38	0.29	22.00
Justiceburg, Texas	1911	362	56	15.47	20.07
SAWN GUM CREOSOTE					
Hutchinson, Kans.	1907	398	189	48.21	22.41
Hutchinson, Ka. M.L.	1907	230	136	59.13	21.53
Plevna, Kansas	1907	262	147	56.11	20.04
Justiceburg, Tex.	1911	338	134	39.64	18.49
Newton, Kansas	1913	147	16	10.88	18.60
Chillicothe, Ill.	1926	336	None	0.00	6.00
SAWN DOUGLAS FIR CREOSOTE					
Barstow, Calif.	1910	12910	11766	91.14	14.50
SAWN BEECH CREOSOTE					
Justiceburg, Texas	1911	307	64	20.85	19.36
Smithshire, Ill.	1912	386	49	12.69	19.42
Marceline, Mo.	1912	99	12	12.12	19.67
Tecumseh, Kans.	1912	161	161	100.00	16.52
Newton, Kansas	1912	157	7	4.46	19.83

Sheet # 3

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AS OF DECEMBER 31, 1932
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Station	Year Inserted.	Original Number Inserted	Total Ties Removed	% Ties Removed From Track	Average Life to 12-31-32
HEWN ENGELMANN SPRUCE CREOSOTE					
Pinta, Arizona	1927	858	None	0.00	5.00
SAWN ENGELMANN SPRUCE CREOSOTE					
Pinta, Arizona	1927	1031	None	0.00	5.00
SAWN WESTERN YELLOW PINE - 50% CREOSOTE, 50% PETROLEUM					
Texico-Lubbock, Tex.	1913	8259	239	2.89	18.85
HEWN SOUTHERN YELLOW PINE, 7 POUNDS MIXTURE - 70% CREOSOTE, 30% PETROLEUM					
Mission-Hutchinson, Kans.	1923	27603	None	0.00	9.00
Saffordville, Kans.	1923	12917	None	0.00	9.00
Saffordville, Kans.	1924	107	None	0.00	8.00
Mission-Hutchinson, Kans.	1925	54	None	0.00	7.00
SAWN SOUTHERN YELLOW PINE, 7 POUNDS MIXTURE - 70% CREOSOTE, 30% PETROLEUM					
Mission-Hutchinson, Kans.	1923	11791	None	0.00	9.00
SAWN RED OAK, 7 POUNDS MIXTURE - 70% CREOSOTE, 30% PETROLEUM					
Mission-Hutchinson, Kans.	1923	1042	None	0.00	9.00
HEWN GUM, 7 POUNDS MIXTURE - 70% CREOSOTE, 30% PETROLEUM					
Saffordville, Kansas	1924	152	None	0.00	8.00
SAWN GUM, 7 POUNDS MIXTURE - 70% CREOSOTE, 30% PETROLEUM					
Saffordville, Kans.	1923	2766	None	0.00	9.00
Saffordville, Kans.	1924	145	None	0.00	8.00
Chillicothe, Ill.	1926	329	None	0.00	6.00
HEWN SOUTHERN YELLOW PINE, 8 POUNDS MIXTURE - 70% CREOSOTE COAL TAR SOLUTION, 30% PETROLEUM					
Chillicothe, Ill.	1925	2104	None	0.00	7.00
Chillicothe, Ill.	1926	2424	None	0.00	6.00
HEWN COTTONWOOD 5 POUNDS CREOSOTE					
Lucy, New Mexico	1923	75	None	0.00	9.00
SAWN COTTONWOOD 5 POUNDS CREOSOTE					
Lucy, New Mexico	1923	75	2	2.67	8.95
HEWN COTTONWOOD, 7 POUNDS MIXTURE, 50% CREOSOTE, 50% PETROLEUM					
Lucy, New Mexico	1923	75	None	0.00	9.00

Sheet # 4

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AS OF DECEMBER 31, 1932
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Station	Year Inserted	Original Number Inserted	Total Ties Removed	% Ties Removed From Track	Average Life to 12-31-32
SAWN COTTONWOOD, 7 POUNDS MIXTURE, 50% CREOSOTE, 50% PETROLEUM					
Lucy, New Mexico	1923	75	None	0.00	9.00
HEWN SOUTHERN YELLOW PINE, 8 POUNDS MIXTURE, 50% CREOSOTE, 50% PETROLEUM					
Saffordville, Kans.	1924	8300	None	0.00	8.00
Mission-Hutchinson, Kans.	1928	363	None	0.00	4.00
Mission-Hutchinson, Kans.	1929	26699	None	0.00	3.00
Mission-Hutchinson, Kans.	1930	131	None	0.00	2.00
SAWN SOUTHERN YELLOW PINE, 8 POUNDS MIXTURE, 50% CREOSOTE, 50% PETROLEUM					
Mission-Hutchinson, Kans.	1927	24	None	0.00	5.00
Mission-Hutchinson, Kans.	1928	3181	None	0.00	4.00
Mission-Hutchinson, Kans.	1929	5893	None	0.00	3.00
SAWN GUM, 8 POUNDS MIXTURE, 50% CREOSOTE, 50% PETROLEUM					
Saffordville, Kans.	1924	141	None	0.00	8.00
SAWN WESTERN YELLOW PINE, 8 POUNDS MIXTURE, 45% CREOSOTE, 55% PETROLEUM					
Pinta, Arizona	1928	2267	None	0.00	4.00
SAWN WESTERN YELLOW PINE, 8 POUNDS MIXTURE, 45% CREOSOTE, 55% PETROLEUM (STEAMED 2 HRS-20 LBS.)					
Pinta, Arizona	1928	439	None	0.00	4.00
SAWN WESTERN YELLOW PINE, 8 POUNDS MIXTURE, 45% CREOSOTE, 55% PETROLEUM (STEAMED 2 HRS-30 LBS.)					
Pinta, Arizona	1928	451	None	0.00	4.00
HEWN SOUTHERN YELLOW PINE, 8 POUNDS MIXTURE, 45% CREOSOTE, 55% PETROLEUM					
Pinta, Arizona	1928	1853	None	0.00	4.00
HEWN ENGELMANN SPRUCE, 8 POUNDS MIXTURE, 45% CREOSOTE, 55% PETROLEUM					
Pinta, Arizona	1928	934	None	0.00	4.00
SAWN ENGELMANN SPRUCE, 8 POUNDS MIXTURE, 45% CREOSOTE, 55% PETROLEUM					
Pinta, Arizona	1928	1210	None	0.00	4.00
HEWN WESTERN YELLOW PINE, 8 POUNDS MIXTURE, 25% CREOSOTE, 75% PETROLEUM					
Acomita, New Mexico	1924	998	1	0.10	8.00
HEWN SOUTHERN YELLOW PINE, 8 POUNDS MIXTURE, 25% CREOSOTE, 75% PETROLEUM					
Acomita, New Mexico	1924	999	None	0.00	8.00

Sheet # 5

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AS OF DECEMBER 31, 1932
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Station	Year Inserted	Original Number Inserted	Total Ties Removed	% Ties Removed From Track	Average Life to 12-31-32
HEWN SOUTHERN YELLOW PINE, 8 POUNDS MIXTURE, 25% CREOSOTE, 75% PETROLEUM (CONT.)					
Whiteface, Texas	1925	557	None	0.00	7.00
Boise City, Kans.	1925	500	None	0.00	7.00
HEWN GUM, 8 POUNDS MIXTURE, 25% CREOSOTE, 75% PETROLEUM					
Boise City, Kans.	1925	253	None	0.00	7.00
Whiteface, Texas	1925	254	None	0.00	7.00
SAWN WESTERN YELLOW PINE, 8 POUNDS MIXTURE, 25% CREOSOTE, 75% PETROLEUM					
Pinta, Arizona	1928	503	None	0.00	4.00
SAWN WESTERN YELLOW PINE, 8 POUNDS MIXTURE, 25% CREOSOTE, 75% PETROLEUM (STEAMED 2 HRS.-20 LBS.)					
Pinta, Arizona	1928	447	None	0.00	4.00
SAWN WESTERN YELLOW PINE, 8 POUNDS MIXTURE, 25% CREOSOTE, 75% PETROLEUM (STEAMED 2 HRS.-30 LBS.)					
Pinta, Arizona	1928	456	None	0.00	4.00
HEWN OHIA UNTREATED					
Stafford, Kans.	1910	132	75	56.82	18.69
SAWN OHIA UNTREATED					
Stafford, Kans.	1910	108	28	25.93	19.25

Appendix C

(3) PILING USED FOR MARINE CONSTRUCTION

Wm. G. Atwood, Chairman, Sub-Committee; G. B. Campbell, C. C. Cook, H. R. Condon, L. H. Harper, G. R. Hopkins, H. E. Horrocks, G. C. Stephenson, C. M. Taylor.

Conclusion

Your Committee recommends that this report be accepted as information.

The Committee submits herewith its report on the present condition of the long-time test pieces under its observation, together with such other pertinent information as has come to its knowledge.

Tropical Timber

ANGELIQUE OR BASRALOCUS *(Dicorynia paraensis. Benth)*

Submerged September 13, 1923. Balboa, C.Z. There was considerable marine growth and the limnoria damage, while not very deep, was general on all surfaces. The pholads were plentiful, confined as usual close to the surfaces. The same was true of the teredoes which were all very small, few in number. The timber is in very good condition otherwise.

MANBARKLAK *(Lecythis ollaria, L.)* Submerged Balboa, C.Z. September 13, 1923.

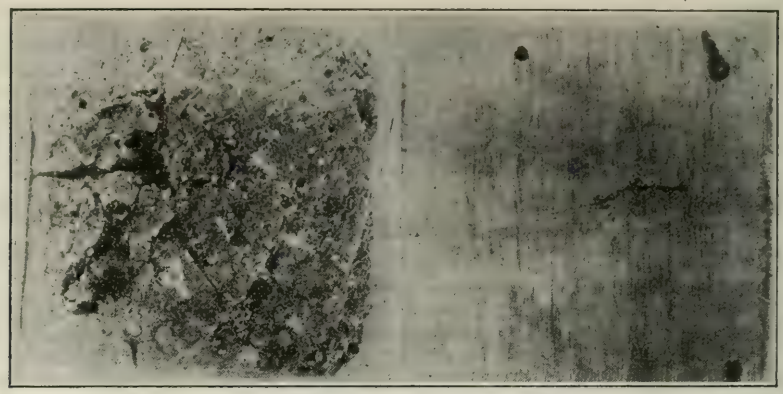
There was considerable marine growth on the surfaces. In general the timber appeared to be very sound. A section was cut from the end (Fig. 1). In this were eight Martesia and six Xylophaga. Teredoes were very few, very small, less than ⅛ inch in diameter, and limited very close to the surfaces, especially the ends. The wood was very hard and in excellent condition.

GREENHEART *(Nectanda rodieoi, Schomb).* Submerged Balboa, C.Z. September 13, 1923.

There was much marine growth and a fair number of pholads. A section was cut. In it were a number of pholads and plenty of teredoes, some ⅜-inch in diameter, but the wood was not yet over-riddled by them. They show no difficulty in working through the wood. Many were dead with silt in the burrows. Otherwise the wood is sound.

GREENHEART.—From Panama Canal Stock. Submerged Balboa, C.Z. September 26, 1931.

One side was clean, the other had much marine growth. There were quite a number of pholad and teredo holes. A 3 inch section was cut from the end. It had many pholads and teredoes were plentiful some ⅝ inch in diameter. A few were dead.



3, 4, Manbarklak, (1613) (Zetek)
(Fig. 1)

Greenheart.—Yellow Heart. Submerged Balboa, C.Z. July 18, 1932.

There was much marine growth and a few pholads. Teredo appeared to be few, small and apparently confined close to the surfaces. Timber in good condition.

Greenheart.—Dark Brown Heart. Submerged Balboa, C.Z. July 18, 1932.

There was much marine growth and some mud. Teredo appear to be few in number, small and close to the surfaces. Timber in good condition.

Greenheart.—Light Brown Heart. Same as above.

Turpentine Wood *(Syncarpia laurifolia)*. U. S. District Engineer, Charleston, S. C.

Submerged at Castle Pinckney, S.C. June 24, 1925. Specimen attacked by teredo on the ends and surface. The remainder of the specimen is solid. About 60 per cent of the useful material still remains.

Panama Canal. Submerged Balboa, C.Z. April 19, 1929.

There is much marine growth and very many pholad cavities. Last August a section was cut from the ends of both specimens and this year there are several new pholads in the cut end. Teredo are fairly plentiful, confined close to the surfaces and all relatively small. The timber is very sound.

PANAMA CANAL

Through the courtesy of Lt. Col. Julian L. Schley, Governor of the Panama Canal Zone, we are able to present the following report on tests being made at Balboa.

"I have to advise that the inspection was performed by Mr. James Zetek on August 7th, and under date of August 21st he has submitted the following report with the attached photographs.

"This report covers examination of timbers in the teredo resistance tests at Balboa, Canal Zone, made by me on August 7, 1933.

"Wherever marine growth is mentioned, it includes ascidians, bryozoans, sponges, 'worms', etc., as well as such other encrusting forms as oysters (including Anomia peruviana), Vermetidae (mollusks), the brachiopod Discinisca cumingii, etc. At least forty species of mollusks were found, those of Crepidula, Crucibulum, Anomia and Ostrea being the most abundant.

"Unless limnoria is mentioned, it was either absent or else its work was negligible.

"The two pholads, Martesia and Xylophaga, are the same species referred to in previous reports. In some timbers these were far more destructive than the teredo. They were especially abundant in Red Satinway (No. 1624–21) which test was closed out largely because of them.

"The principal teredo found was Neobankia zeteki Bartsch. In only one case was Teredora panamensis Bartsch found.

"Most of the untreated timbers that show a high resistance to teredos, are very hard, heavy, and difficult to work. Some have a twisted grain, and Kolaka (No. 1637)

was almost impossible to split with a sharp axe. Wherever it is indicated that the wood was sound, or in excellent condition, it means just that, except for the parts damaged by pholads or teredos."

(A) UNTREATED TIMBERS

"MALABAYABAS, Philippine Islands, No. 1606–9; 12″ × 12″ × 13″; submerged September 13, 1923. This wood is very heavy. A section 1½″ thick was cut from the end. There was much marine growth on the surfaces and a large number of Martesia and Xylophaga openings. In the section cut were about 60 of these pholads, but teredos very very few in number, small, and entirely confined very close to the surface. Teredo work was negligible. The wood is very hard and sound, but it splits rather easily because of the even grain.

"SPONSE HOEDOE *(Licania macrophylla Bentham),* from Dutch Guiana, No. 1610–5; 8″ × 8″ × 24″, submerged September 13, 1923. There was little marine growth, gribble damage not severe but more than last year. The sides show many openings of the two pholads. Last year a section was cut from the end. Another section was cut this year. In this section were about 80 pholads. Many of these were dead, and there was mud and silt in the cavities. Teredos were few in number, small, confined close to the surfaces, especially the end. Most of these were dead, with mud and silt in the burrows. The wood is very hard, with twisted grain, and very sound.

KAJOL LARA *(Metrosideros sp.),* from the Celebes, No. 1615–11; 6½″ × 6½″ × 30″, submerged October 26, 1925. Very little marine growth. Much mud present. A section was cut from the end. Very few pholads were present. Teredos were few, very small, confined to area ⅜″ from the end. Very little gribble work. The wood was very hard and in excellent condition.

FOENGO *(Parinarium campestre Aubl.),* from Dutch Guiana, No. 1608–4; 8″ × 8″ × 24″, submerged September 13, 1923. There was considerable marine growth and a fair amount of gribble damage. Last year a section was cut from the end, and another one was cut at this time. There were 8 Martesia, 12 Xylophaga and 1 Lithrophaga in this section. Teredos were plentiful, all small, ⅛ to $\frac{3}{16}$ inch in diameter, not more than ¾ inch penetration. Some were dead. The wood is hard and very sound.

INGIEBARKI *(Licania heteromorpha Bentham),* from Dutch Guiana, No. 1611–6; 6½″ × 7″ × 24″, submerged September 13, 1923. There was much marine growth and the surfaces were badly damaged by gribble. A small section was cut from the end. It had about 40 pholads, all alive. There were many live teredos, small, some $\frac{3}{16}$ inch in diameter, within 1″ of the surfaces. The wood is very hard and except for the damage noted, in excellent shape.

RED SATINWAY, from New South Wales, No. 1624–21; 6″ × 6″ × 24″, submerged April 19, 1929. There was an abundance of marine growth on all surfaces and a very large number of pholad cavities. Teredos were not numerous, confined rather close to surfaces. They were alive, some $\frac{5}{16}$″ in diameter. The wood otherwise was very sound and extremely difficult to split, very hard and with a twisted grain. It was almost impossible to dissect. CLOSED.

ANOURA *(Conepia Sp.),* from Dutch Guiana, No. 1609–2; 8″ × 8″ × 24″; submerged September 13, 1923. There was a fair amount of marine growth. Gribble damage was severe. Last year a section was cut from the end. Another was cut this time. In it were about 30 pholads, most of them dead, with much mud and silt in the cavities. One live Lithophaga was found. In addition to N. zeteki, T. panamensis was also present. The teredos were not numerous, all small, confined close to surfaces, penetration not over one inch from end. Most of these were dead, with mud in the burrows. Some were $\frac{3}{16}$ inch in diameter, alive. The wood was very hard and in excellent condition.

KOLAKA, from the Celebes, No. 1637–13; 6″ × 6″ × 60″; submerged April 15, 1932. The surfaces were in fine shape with very little marine growth, and no gribble attack. No teredo holes were seen and a small section from the end showed nothing, not even pholads. Because of its size, the timber was cut in two and one piece will be used in teredo tests, the other in termite tests. The latter showed no indications of pholads or teredos. The wood is VERY hard and sound, the grain in places very much gnarled.

KAJOL MALAS *(Parastemon urophyllus),* from Sumatra, No. 1616–12; 6″ × 6″ × 30″; submerged October 26, 1925. This timber was resting on a concrete sill and it would appear that on August 9, 1932, with the tide high, when it was lowered into its place, it was allowed to rest on the sill instead of left to hang free. This means that each day at low tide it was not in water for a whole year. The marine growth was scant

but gribble damage was severe. There were a few pholad cavities. Teredos appeared to be few in number, all small, otherwise the timber is in excellent condition.

Alazano *(Calcycophyllum candidissimum)* (Vahl DC.), from Panama, No. 1627–8; 6″ × 6″ × 30″, submerged October 17, 1929. There was considerable marine growth. The surfaces show a large number of pholad cavities. Teredos are plentiful but the timber is still quite sound. The exact teredo picture was to be seen only in cut sections, as last August, and quite probably next August this test will have to be closed.

Alcornoque *(Dimorphandra mora B. & H.)*, from Panama, No. 1617–14, all heartwood; 6″ × 6″ × 53″; submerged November 22, 1927. Much marine growth on all sides and end. There are several pholad cavities. Teredos are not plentiful, are all small confined close to surfaces. Last August a 5″ section was cut from the end. This year the cut end is very sound. The timber is in excellent condition.

Brush Box, from New South Wales, No. 1625–22; 6″ × 6″ × 24″; submerged April 19, 1929. There was much marine growth. There appears to be more pholads than last time. Teredos are fairly plentiful, all small and close to the surfaces. The timber is very sound.

(B) TREATED TIMBERS

Amarillo *(Chlorophora tinctorea)*, treated with A.R.E.A. No. 1 creosote; No. 1630–30; 9½″ × 12½″ × 9′, one end scarfed after treatment; submerged September 20, 1930. The scarfing exposes wood with less treatment hence gives teredos a better chance to enter. Much marine growth. In general the timber is in excellent condition, but the scarfed surfaces show many holes. Similar holes, but not so many, are in the ends and sides. A two inch section was cut from the scarfed end, continuing the cut backward. This section shows the impregnation was not deep nor too good. In this small piece there were at least 40 teredos, most of them dead, some ⅜-inch in diameter.

Panama Canal Copper Cement Treatment. Seven tests, installed April 20, 1933. The treatment consists of 8 lb. ground copper cement, one gallon pine tar, as follows: heat the tar and stir into it the cement, dilute with gasoline till thin enough to apply cold. I understand it was suggested by J. H. Coleman of the Cia. Salitre de Chile, Valparaiso. For brevity, these tests are marked P.C. Cu Cement Paint. From my observations I do not think this treatment will amount to much. It is easily rubbed off and is too thin to last long.

P.C. Cu Cement Paint, No. 1714–29, creosoted fir, P.C. stock, ends only coated with the paint, size 3″ × 12″ × 30″. There was considerable marine growth and the wood seems to be sound. I did not cut into it.

P.C. Cu Cement Paint, No. 1715–31, creosoted fir, P.C. stock, ends only coated with the paint, size 3″ × 12″ × 30″. Same as preceding one.

P.C. Cu Cement Paint, No. 1716–32, untreated fir, P.C. stock, coated all over with the paint, size 6″ × 6″ × 30″. Much marine growth, the bicalce Anomia peruviana very plentiful. Apparently sound.

P.C. Cu Cement Paint, No. 1717–33, untreated yellow pine, P.C. stock, coated all over with the paint. Size 6″ × 6″ × 30″. Much marine growth. Apparently o.k.

P.C. Cu Cement Paint, No. 1718–34, untreated almendra, P.C. stock, coated all over with the paint. Same as preceding one. 6″ × 6″ × 30″.

P.C. Cu Cement Paint, No. 1719–35, untreated greenheart, P.C. stock, coated all over with the paint, size 6″ × 6″ × 30″. Same as preceding.

(C) SPECIAL TEST

This is a special test installed January 19, 1933, consisting of a 2″ × 12″ plank of untreated fir, P.C. stock, to which were nailed 7 pieces of untreated fir, P.C. stock, 3⅝″ × 3⅝″ × 9″. Each month, starting with February, one of these small blocks was removed and carefully examined. The object was to learn how fast teredos enter and work and to obtain material for study, especially valves and pallets. The blocks are referred to below by their age.

1 month,—surfaces show many small teredo openings. The inside was sound, and the teredos, about 20 in number, very very small, ⅛″ and less in diameter, all alive, close to the surfaces.

2 months,—much like preceding except that there are more teredos, larger, ⅛ to $\frac{3}{16}$″ in diameter and more destruction. The center is not very bad. All teredos were alive.

3 months,—large number of live teredos, ¼″ to $\frac{5}{16}$″ in diameter, even in the center of the block. Most destruction near the surfaces.

4 months,—great amount of teredos, ¼″ to ⅜″, all alive, wood well riddled throughout.

5 months,—much like preceding except that there were more teredos and the destruction is more pronounced. The surfaces, except for the number of tiny teredo openings, do not indicate condition within.

6 months,—very much like preceding one. Destruction greater.

7 months,—thoroughly riddled, practically finished, most of the teredos dead and most foul odor.

The 2 × 12 plank,—completely riddled, most of the teredos dead, many very putrid, with most foul odor. Teredos ⅜″ to $\frac{7}{16}$″ in diameter. A few pholads were in this plank.

This special test not only shows how fast teredos will work (though this is nothing new), but it served as a control, proving that teredos are present.

In the above report, as in previous reports, the identifying numbers of the specimens consist of two parts, namely, that before the dash indicating the Panama Canal test number, and that after the dash indicating the rack in which installed.

CHEMICAL WARFARE SERVICE SPECIMENS

Series No. 1

These test pieces were treated in 1924 and 1925 by the Chemical Warfare Service in their experimental plant at the Edgewood Arsenal. Treatment was with the following compounds:

No. 1. 1 per cent solution of ammoniacal copper carbonate.
No. 2. 1 per cent dyphenalamine chlorarsene in creosote.
No. 3. 0.75 per cent diphenylamine chlorarsene and 0.5 per cent phenyldichlorarsene in fuel oil.

No. 1 Treatments:

Test pieces at Charleston, S.C., Pensacola, Fla. have been practically destroyed, one piece at Coco Solo, C.Z. is very heavily attacked, but the other one much less.

San, Juan, P.R. Submerged 1925. Attacked by limnoria, slight teredo attack.

San Francisco Bay, Calif. Submerged July 21, 1925 at Oakland and Peralta St. Slip (moved from Port Costa). Both pieces show light to moderate limnoria attack.

Puget Sound Navy Yard. Submerged from Piers 4 and 8 in 1925. Both pieces heavily attacked by limnoria and Bankia and test discontinued.

No. 2 Treatments:

District Engineer, Charleston, S.C. Submerged at Castle Pinckney, June, 1925. One piece in good condition except for a few teredo holes, the other destroyed by teredo.

Superintendent of Lighthouses, San Juan, P.R. Submerged 1925. In good condition. No evidence of attack.

U.S. Naval Air Station, Pensacola, Fla. Submerged July 8, 1925. One piece lost, the other shows moderate attack by limnoria on the ends.

U.S. Fleet Air Base, Coco Solo, C.Z. Submerged 1925. In very good condition, showing only a minor attack by limnoria around a knot.

Southern Pacific Company. Submerged June 1925. Light limnoria attack on both test pieces.

Puget Sound Navy Yard. Submerged November 1925. Both pieces hard and sound with no sign of borer attack.

CHEMICAL WARFARE SERVICE

Series No. 2

These test pieces were treated at the Edgewood Arsenal in 1931 with the following materials.

A A.R.E.A. No. 1 Creosote.
B A.R.E.A. No. 1 Creosote with 0.71 methylarsenious oxide.
C A.R.E.A. No. 1 Creosote with 0.77 diphenylamine chlorarsene.
D A.R.E.A. No. 1 Creosote with 2.5 dinitrophenol.
E Petroleum residium with 2.5 per cent dinitrophenol.
F Petroleum residium with 0.8 per cent methylarsenious oxide.
G Petroleum residium with diphenylamine chlorarsene.

Inspection reports follow:

"A" Treatments:

Fort Tilden, N.Y. No attack except slight limnoria erosion on one end of one piece.
Castle Pinckney, S.C. Slightly attacked by limnoria on ends.
Naval Air Station, Pensacola, Fla. Slight limnoria attack on ends of both pieces.
Balboa, C.Z. Apparently in good condition.
Bureau of Lighthouses, San Juan, P.R. Good condition.
Southern Pacific Co. Oakland Pier. Very light limnoria attack.
Southern Pacific Co. Peralta Slip. No attack this year.
Puget Sound Navy Yard. A few small Bankia holes in the end.
Pearl Harbor Navy Yard. Light limnoria attack on both pieces.
Cavite Naval Station. No report received.

"B" Treatments:

Fort Tilden, N.Y. Very slight limnoria erosion on one end of one piece.
Castle Pinckney, S.C. Light limnoria attack on sides and ends.
Naval Air Station, Pensacola, Fla. Slight limnoria attack on end of one piece and a little heavier attack on the other.
Balboa, C.Z. Apparently in excellent condition.
Bureau of Lighthouses, San Juan, P.R. Good condition.
Southern Pacific Company, Oakland Pier. Very light limnoria attack.
Southern Pacific Company, Peralta Pier. Slight limnoria attack on one end.
Puget Sound Navy Yard. Several Bankia holes in one piece, other piece more heavily attacked and discarded.
Pearl Harbor, H.I. Navy Yard. Some limnoria attack on sides of one piece and about 20 holes in the other.
Cavite Naval Station. Report not received.

"C" Treatments:

Fort Tilden, N.Y. Very slight limnoria attack.
Castle Pinckney, S.C. Slight limnoria attack.
Naval Air Station, Pensacola, Fla. Slight limnoria attack on ends.
Balboa, C.Z. Some limnoria attack. Several Martesia and Xylophaga, found in one end about 20 teredo, all dead.
Supt. of Lighthouses, San Juan, P.R. Good condition.
Southern Pacific Co. Oakland Pier. No attack.
Southern Pacific Co. Peralta Pier. No attack.
Puget Sound Navy Yard. A few Bankia entrance holes in the ends of both pieces.
Pearl Harbor, H.I. Navy Yard. Both pieces lightly attacked by limnoria.
Cavite, P.I. Naval Station. No report.

"D" Treatments:

Fort Tilden, N.Y. Slight limnoria attack on one piece, none on the other.
Castle Pinckney, S.C. Slightly attacked on ends by limnoria.
Naval Air Station, Pensacola, Fla. No attack.
Balboa, C.Z. Apparently in good condition.
Supt. of Lighthouses, San Juan, P.R. Good condition.
Southern Pacific Co. Oakland Pier. Very light limnoria attack.
Southern Pacific Co. Peralta Pier. No attack.
Puget Sound Navy Yard. Slight limnoria attack and a few Bankia entrance holes.
Pearl Harbor, H.I. Navy Yard. One piece very lightly and one more heavily attacked by limnoria.
Cavite, P.I. Naval Station. No report.

"E" Treatments:

Fort Tilden, N.Y. One piece good, one with slight teredo attack.
Castle Pinckney, S.C. Heavily attacked by teredo about one-half destroyed.
Naval Air Station, Pensacola, Fla. One piece lost, other shows heavy attack by limnoria with some Martesia and teredo.
Balboa, C.Z. Limnoria damage severe. Many pholad openings as well as teredo A section was cut from the end. It had several pholads alive, some of the Martesia very large. There were about 90 teredo in this small section, most of them dead. Some were ⅜ inch in diameter. There was much petroleum residue in the holes.

Supt. of Lighthouses, San Juan, P.R. One piece in good condition, the other showing light limnoria and teredo attack.
Southern Pacific Co. Oakland Pier. No attack.
Southern Pacific Co. Peralta Pier. Very light limnoria attack.
Puget Sound Navy Yard. Pieces practically destroyed in first year.
Pearl Harbor, H.I. Navy Yard. Both pieces show moderate attack.
Cavite, P.I. Naval Station. No report.

"F" Treatments:

Fort Tilden, N.Y. Very slight limnoria attack.
Castle Pinckney, S.C. Heavily attacked only about 65 per cent useful material remaining.
Naval Air Station, Pensacola, Fla. One piece half destroyed by limnoria, and also contains a few teredo. The other piece heavily attacked by limnoria and also a few teredo.
Balboa, C.Z. Much damage by limnoria and considerable marine growth. About 10 specimens of Martesia were recovered. The timber was thoroughly riddled by teredo, some $\frac{7}{16}$ inch in diameter and one 15 inches long. Teredo were in both heart and sap wood, also in treated area. Test closed.
Supt. of Lighthouses, San Juan, P.R. Slight limnoria attack, no teredo.
Southern Pacific Company, Oakland Pier. Very light limnoria attack.
Southern Pacific Co. Peralta Pier. Very light limnoria attack.
Puget Sound Navy Yard. Pieces practically destroyed in first year.
Pearl Harbor, H.I. Navy Yard. Piece at Coaling Plant shows heavy limnoria attack and attack by Martesia and probably teredo while piece on the Marine Railway seems to be less heavily attacked.
Cavite, P.I. Naval Station. No report received.

"G" Treatments:

Fort Tilden, N.Y. Limnoria attack in one piece, ¾-inch deep in places and ½-inch on other piece.
Castle Pinckney, S.C. Lightly attacked by limnoria.
Naval Air Station, Pensacola, Fla. One piece ⅝ eaten away by limnoria and the other heavily attacked.
Balboa, C.Z. Limnoria damage severe. A section was cut from the end. It had a few pholads. Teredo were plentiful in both sap and heart wood and in treated section. Most of the teredo were dead.
Supt. of Lighthouses, San Juan, P.R. Heavily attacked by both limnoria and teredo. Test closed.
Southern Pacific Co. Oakland Pier. Very light limnoria attack.
Southern Pacific Co. Peralta Pier. Very light limnoria attack.
Puget Sound Navy Yard. Medium limnoria attack.
Pearl Harbor, H.I. Navy Yard. Medium limnoria attack.
Cavite, P.I. Naval Station. No report.

COPPER RESINATE TESTS

A few of these test pieces remained at various test stations, but have now been practically all destroyed by limnoria, teredo and pholads. These test pieces were all submerged in 1930.

SAN FRANCISCO BAY CREOSOTE TESTS

Report of Inspection August 23, 1933 of Specimens Furnished Dr. Hermann von Schrenk and Col. Wm. G. Atwood, and Installed in San Francisco Bay Area
(P = Pine F = Fir)

Barrett Manufacturing Company Material

Placed at Station B, Pier 7, San Francisco, January 1923. Moved to Biological Station Oakland Pier, % S.P. Co. December 1925. These specimens still show no attack except lightly by Limnoria.

A

Gate	Specimen No.	Treatment	Condition August 23, 1933
B–4	P–1	Coke oven original oil	P–1, very light limnoria attack.
	P–2	" " solids removed	P–2–3 Slightly eroded by limnoria.
	P–3	" " acids "	No fresh attack in 1933.
	P–4	" " bases "	P–4 early attacks same as P–2–3. No fresh attack during 1933.
B–5	P–5	Coke Minus Residue 360 deg. C.	P–5–6–7 Slightly eroded by limnoria on ends in 1932;
	P–6	Coke Minus Fraction 239 deg. C. 270 deg. C.	P–5 also on sides. No attacks in 1933.
B–5	P–7	Coke, Minus Fraction up to 230 deg. C.	
	P–8	Coke, Minus Fraction 270 deg. 360 deg. C.	P–8 Attacks previous years somewhat greater than for P–5–6–7. No attack in 1933.
B–6	P–9	Vertical Retort Original Oil	P–9–10–11–12 Light limnoria attack on ends and sides. A little more pronounced on P–12. Little change during 1933.
	P–10	Ditto Minus solids	
	P–11	Vertical Retort Original Oil Minus acids	
	P–12	Vertical Retort Original Oil Minus bases	
B–7	P–13	Vertical—Minus Residue above 360 deg. C.	Very light limnoria attack in 1933.
	P–14	Vertical—Minus fraction 230 deg. C.–270 deg. C.	Ditto.
	P–15	Vertical—Minus fraction up to 230 deg. C.	Light limnoria on ends in 1933.
	P–16	Vertical—Minus fraction 270 deg. C. to 360 deg. C.	Light general limnoria attack in 1933 in addition to previous light attack.
B–8	F–1	Coke oven Original Oil	F–1, 2, 3, 4 all previously slightly eroded on ends.
	F–2	" " Solids removed	Do not show any fresh attack during 1933.
	F–3	" " Acids "	
	F–4	" " Bases "	
B–9	F–5	Coke Minus Residue 360 deg. C.	Very light limnoria attack 1933.
	F–6	Coke Minus Fraction 239 deg. C. 270 deg. C.	No fresh attack.
	F–7	Coke Minus Fraction up to 230 deg. C.	Very light limnoria attack on one end.
	F–8	Coke Minus Fraction 270 deg. C. 360 deg. C.	No fresh attack.
B–10	F–9	Vertical Retort Original Oil	Light limnoria attack on ends.
	F–10	" " Minus solids	" " " " "
	F–11	" " " acids	" " " " "
	F–12	" " " bases	" " " " "
B–11	F–13	Vertical Retort Minus residue about 360 deg. C.	Very light limnoria attack on one end.
	F–14	Vertical Retort Minus Fraction 230 deg.–270 deg. C.	No fresh attack in 1933.
	F–15	Vertical Retort Minus Fraction up to 230 deg. C.	" " " " "
	F–16	Vertical Retort Minus Fraction 270 deg. C.–to 360 deg. C.	Light limnoria attack.

1933 REPORT ON TEST PILES

The following Tables 1–A to 1–D, give the 1933 condition of four sets of Test Piles driven in 1919 and 1920 at Seattle, Tiburon, in San Francisco Bay, San Pedro and San Diego. Each set originally consisted of seven piles, including the following:

3 Old creosoted fir piles originally driven	1890	Table 1–A
1 ditto	1901	" 1–B
2 New freshly creosoted fir piles originally driven	1919–1920	" 1–C
1 New untreated fir pile originally driven.....	1919–1920	" 1–D

The untreated piles were destroyed in three or four years as shown in Table 1–D, leaving six piles in each set.

The set at San Diego was exposed for test by the Atchison, Topeka & Santa Fe Railway Company in their wharf No. 63, until the wharf was dismantled in 1925. After being repaired they were redriven by the Southern Pacific Company at Long Beach, California and the test continued.

It has been customary to make an annual diver inspection of the test piles which the Northern Pacific installed under its Dock No. 1 at Seattle, but as inspections of recent years have shown these piles entirely free from Teredo, the diver inspection at Seattle was not made in 1932, and data of 1933 inspection had not been received at the time of forwarding the 1933 report.

Table 1–A

Creosoted fir piles from Southern Pacific Company Old Long Wharf, Dock "A" Oakland, originally driven in 1890. Pulled in 1919 and redriven elsewhere. Exposed to Marine Borer attack forty-three years to date.

	Redriven for Test			*1933 Inspection*	
Mark	*Date*	*Railroad*	*Location*	*Remarks*	*Borers*
A 6	1920	N.P. Ry.	Seattle		
A 8	"	"	"		
A32	"	"	"		
A19	1919	NWP. RR.	Tiburon	4⅛" to ¼" checks bet. high & low tide. No evidence of borers. Condition good.	
A28	1919	"	"	Condition good. No evidence of borers entering pile.	
A29	"	"	"	Condition good. No evidence of borers entering pile.	
A 5	"	S.P. Co.	San Pedro	Slight limnoria attack of 1924 not now active. Pile coated with small barnacles. No other change.	
A20	"	"	"	Same as above.	
A34	"	"	"	" " "	
A 2	1920	A.T. & S.F.	San Diego	Pulled in 1925.	
A 2	1925	S.P. Co.	Long Beach	Holes attacked, repaired in 1925. No further attack to date. Destroyed 8/8/33 by Steamer Wapama.	Limnoria
A 7	1920	A.T. & S.F.	San Diego	Pulled in 1925.	
A 7	1925	S.P. Co.	Long Beach	Holes of attack in 1925 repaired. No further attack.	Limnoria
A33	1920	A.T. & S.F.	San Diego	Pulled in 1925.	
A33	1925	S.P. Co.	Long Beach	Holes of borer attack repaired in 1925. No further attack to date.	Limnoria

TABLE 1–B

Creosoted Fir piles from Southern Pacific Company Old Long Wharf Dock "E" Oakland, Originally Driven in 1901. Pulled in 1919 and re-driven elsewhere. Exposed to Marine Borer attack thirty-two years to date.

Redriven for Test				*1933 Inspection*	
Mark	*Date*	*Railroad*	*Location*	*Remarks*	*Borers*
E46	1920	N.P. Ry.	Seattle		
E42	1919	NWP. R.R.	Tiburon	Checked between high and low tide. Borers have entered pile in 3 places. A hole was filled with cement sometime back and covered with a copper plate. The copper plate is practically eaten away but the filled hole is in good condition.	
E38	1919	S.P. Co.	San Pedro	Slight Limnoria attack in 1927 at low water, also 1929 and 1932. Cavity 1½″ × 3″ × 2″ deep; 2′ below high water, repaired with hot asphalt, sand and cement and covered with copper plate 3–33. Otherwise pile OK.	Limnoria
E50	1920	A.T. & S.F.	San Diego	Pulled in 1925.	
E50	1925	S.P. Co.	Long Beach	Light attacks at low water 1927 and 1929. Borers again working in small spot 2′ below high water.	Limnoria

TABLE 1–C

Freshly Creosoted Fir Piles Exposed to Marine Attack, 12 years to date.

Re-Driven for Test				*1933 Inspection*	
Mark	*Date*	*Railroad*	*Location*	*Remarks*	*Borers*
47	1920	N.P. Ry.	Seattle		
48	"	"	"		
43	1919	NWP. R.R.	Tiburon	No evidence of borer attack. Pile in good condition.	
44	"	"	"	Few checks between tides but no evidence of borers entering pile.	
40	"	S.P. Co.	San Pedro	No attack to date. Pile coated with small barnacles.	
41	"	"	"	Same as 40. No attack.	
51	1920	A.T. & S.F. Ry.	San Diego	Pulled in 1925.	
51	1925	S.P. Co.	Long Beach	Some holes showing in 1925 were repaired. Some borers at low water in 1932 but borers not working in 1933.	Limnoria
52	1920	A.T. & S.F. Ry.	San Diego	Pulled in 1925.	
52	1925	S.P. Co.	Long Beach	Holes of attack in 1925 repaired. No sign of any borers at this time.	Limnoria

NORTHERN PACIFIC RAILWAY COMPANY
CONDITION REPORT

Test piles placed March 29 and 30, 1920, between bents 47 and 48 and 48 and 49, south side of Pier No. 1, Seattle, Wash. Identification marks on copper plates near top of piles on east side.

Underwater Inspection made Nov. 24th, 1933. W. S. Benjamin, Diver.

N. P. Ry. Marks	S. P. Ry Marks	Condition and date of last inspection
A	Pile 48 freshly creosoted 1919	Check near bottom shows teredo sign, also small check 15' above bottom. No harm done.
B	Pile 49 Untreated 1919	Dropped out in 1923.
C	Pile 47 Freshly treated 1919	No sign of live teredo
D	Dock E Pile 46 1901-1919	" " " " "
E	Dock A Pile 8 1899 - 1919	" " " " "
F	Dock A Pile 6 1899 - 1919	" " " " "
G	Dock A Pile 32 1899 - 1919	" " " " "
H		" " " " "
I		" " " " "

The only sign of live teredos working was on Pile A and this was slight. This pile is as good as perfect in spite of the slight action noted.

Signed E. E. Hopkins

Piles E,F,G.	From S.P.Ry. had been in service in Long Wharf, Oakland, Cal., Dock A, from 1899-1919, 22 years. Removed Apr. 10, 1919.
Pile D.	From same company, had been in service in same wharf, Dock E, 1901-1919, 18 years. Removed April 1919.
Piles A, C.	From same company, freshly treated August 1919 but not previously used. Boiling Process, 14 pounds per cubic foot.
Pile B.	From same company, not treated, but peeled and driven in same condition as received.
Pile H.	Freshly treated, Pacific Creosoting Company March 1919, boiling under vacuum, 14 pounds creosote per cubic foot.
Pile I.	Freshly treated, Coleman Creosoting Company March 1919, steaming process, 16 pounds creosote per cubic foot.

Object of test to find out if possible how water in Puget Sound at Seattle compares with San Francisco Bay, Oakland, Cal., with reference to activity of marine borers also if preservative used in long lived Oakland piling had a more retarding effect on the borers than that generally used at Puget Sound points.

TABLE 1–D

Untreated Fir Piles Exposed to Marine Borer Attack

Driven for Test				*1933 Inspection*	
Mark	*Date*	*Railroad*	*Location*	*Remarks*	*Borers*
49	1920	N.P. Ry.	Seattle	Broken off at mud line in 1923.	Limnoria Bankia
45	1919	NWP R.R.	Tiburon	Broken off at mud line in 1923	Limnoria Bankia Teredo Navalis
39	1920	S.P. Co.	San Pedro	Pile was eaten off and missing in 1925.	Limnoria and probably Bankia

CHEMICAL WARFARE SERVICE

Through the cooperation of the Chemical Warfare Service, we are able to present the following report on the work in their laboratory at Edgewood Arsenal and their tests at Beaufort, N. C.

Report on Tests at Beaufort, N. C., Marine Piling Investigation

(I.) FIRST SERIES. Test pieces 30″ × 10″ × ⅞″, referred to in A.R.E.A. Bulletin 332, December, 1930, pp. 297–303.

The terrapin pens holding these test pieces were washed out by a storm in March, 1932. Following the storm, one test piece from each set was salvaged and reinstalled in the open sea, where it had been found the attack was more severe.

To date, the following boards have survived without serious attack by either shipworm or limnoria:

Set No.	*Vehicle*	*Toxic*
4	C	DM
9	C + FO	Cu Resinate
13	C	—
25	C	—
40	C + A + N	CH_3AsO
45	C + N	Bromacetophenone
46	C + N	DNP
47	C + N	C_6H_5AsO

Abbreviations:

A — Anthracene
C — Creosote
DM — Diphenylaminechlorarsine
DNP — Dinitrophenol
FO — Fuel Oil
N — Naphthalene

All boards containing $AsCl_3$ showed practically no attack, but were so badly burned by the toxic as to be useless for structural purposes. Consequently, they were discarded.

(II.) SECOND SERIES. Test pieces 8″ × 4″ × ¾″.

A. APPARATUS AND PROCESS.—The impregnations were made in an apparatus designed and assembled at Edgewood Arsenal. It consisted essentially of an impregnating chamber and a supply tank. It was equipped with suitable fittings and gages to make an impregnation by the vacuum-pressure process.

B. MATERIALS.

1. Vehicles.

The following vehicles for carrying the toxics, both alone and in combination, have been used:

a. *Creosote,* A.W.P.A. No. 1. The distillation range and float test of the creosote used complied with the specifications for creosote, A.W.P.A. Grade 1.

b. *Creosote* minus the fraction distilling below 235°C. Sixteen liters of creosote were distilled and the fraction coming over below 235°C. was rejected. The remaining material was used in comparison with the original creosote.

c. *Chlorinated Creosote.* A number of impregnations were made with chlorinated creosote. The creosote was cooled to 15°C. and the chlorine bubbled through for various lengths of time. The chlorine absorbed was determined by the increase in weight of the creosote. This material was brushed on as well as impregnated into the wood by the vacuum-pressure process.

d. *Residuum Oil.* The residuum oil used was obtained from the Standard Oil Company. The analysis of the oil used was as follows:

Specific Gravity .....0.9885 at 98.9°C.
Viscosity Saybolt .....58 sec. at 98.9°C.

This oil has no toxic properties but acts as a water repellent. A sample of petroleum residuum was also obtained from the Santa Fe Railway Co. This oil is used by them mixed with creosote to impregnate railroad ties.

e. *Petroleum Oil.* The light oil used was obtained from the Standard Oil Company.

f. *Furfural.* This material was used due to its property of penetrating wood deeply and its solvent action on DM. Ammonia gas was used in some cases to lock the DM and furfural in the wood. The hydrofuramide formed by their interaction is less soluble than furfural.

2. Toxics.

The per cent of toxic used was based on the weight of the vehicle. There have been innumerable toxics impregnated into wood to increase its serviceable life. The toxics usually used are salts of copper and arsenic, phenols, cresols, lysol, etc. A great many patents have been taken out on the use of the various toxics. It is to be noted that practically all toxics tried are toxic to men, while heir toxicity to borers is not definitely proved.

The following compounds have been tested in wood since 1929:

Furfural
Triethanolamine oleate
DM
DM and Furfural
DM and Furfural + NH_3 gas.
Chlorinated Creosote
Colloidal Copper from Asphalt Product Co.
Dichlorxylenol
Ethylenedichloride
Triphenylarsine
Methylarsenious Oxide
Benzylarsonic Acid
Dinitrophenol
Phenyldichlorarsine
Phenylarsenious Oxide
Hydrofuramide
Paris Green
Diphenyl
Copper Sulfate
Potassium Ferrocyanide

These toxics were tested in various percentages, alone and in combination, after impregnating in wood.

3. Wood Test Pieces.

The wood in which the toxics and vehicles were tested was a good grade of pine. Wood is readily attacked by borers and while some tropical species have shown some resistance, pine is quickly attacked and riddled by borers. The air seasoned pine was sawed into 8 × 4 × ¾-in. sections which after impregnating are termed "test pieces". The pieces having defects such as knots, checks, etc., were used as the bait pieces to

accelerate attack on the impregnated test pieces. In a majority of cases, the test pieces had a toxic in solution in the impregnating vehicle. Where a toxic was not included it was for the purpose of getting a comparison on the vehicle with and without a toxic.

(C.) Installation of Test Pieces at Piver's Island, Beaufort, N. C.

The method of installation was as follows:

Each 8 × 4 × ¾-in. test piece had a No. 9 screw-eye fitted in the center of one of the 8 × ¾-in. sides. When ready to install, a ¼-in. cable was threaded through the screw eyes. The test pieces were kept separated by a flexible wire wound on a 3d nail driven in the 4 × ¾-in. end. Two steel stakes were driven in the water and the ends of the cable and wire were attached to the stakes. The test pieces installed in this manner have withstood a number of severe storms. The installation of new impregnated pieces was usually made in March or April of each year.

The intensity and distribution of attack were determined by nailing blocks of unimpregnated wood to alternate test pieces. These blocks, which are termed "baits", are ordinarily destroyed by borers in one season, and must be replaced each year by new ones.

When the bait pieces become too crowded, the shipworms are forced to seek entry into the impregnated pieces, thus giving a measure of the efficiency of the toxic against the adult borer.

Since some of the vehicle and toxic in an impregnated test piece may be transferred to the attached bait piece by contact or by leaching, thus inhibiting attack on the baits by borers, controls of untreated wood were installed at regular intervals along with the treated pieces. It may be mentioned here that this effect of a protected area around an impregnated test piece has never been noted, still the possibility exists and must be allowed for. These control pieces usually have disappeared after one season, leaving nothing but the screw eye to show where they were originally placed on the line.

There have been 736 numbered test pieces installed and tested in this series. The numbering is progressive and increases a hundred each year. As listed in Table 1, the first set included 125 to 180. These pieces were first installed for test in a fish pond on April 3, 1930. (The fish pond is a space enclosed by cement walls and connected to tide-water by a gate). This set was staked outside the walls on April 5, 1932. The set numbered 245 to 293 was installed in the fish pond on April 13, 1931. On October 10, 1931 they were staked outside the sea wall. The test pieces numbered 300 to 355 were installed outside the sea wall in their present location on April 5, 1932, and the 400 series in April, 1933.

(D.) Inspection of Test Pieces.

The inspection of the test pieces for borer attack is made in October. This month is about the end of the breeding season for shipworm at Beaufort, N. C. The inspection is made by removing the cables on which the test pieces are strung, together with the attached test pieces, from the water. Each test piece is given a thorough inspection for limnoria and shipworm attack. All the barnacles and oyster spat are removed from the piece during this examination, as the accumulation of barnacles and oyster spat reduces the area available for attack. The nail used in the test piece is pulled and any corrosive effect of the toxic or vehicle noted. When the inspection is completed new bait pieces and controls are put on and the line replaced for further test. The method of installation and the effect of borers on test pieces are shown in photograph No. 6198.

(E.) Experimental Results.

In the following table, the number, vehicle, toxic, pieces installed, pieces attacked, kind of attack (whether limnoria or shipworm), pieces discarded, rating, and pound per cubic foot, are noted.

The column "Rating" gives an approximation of the comparative efficiency of the particular set. Test pieces attacked by shipworm are discarded as of no value. The limnoria attack is rated on the area and depth of attack. The figure for rating is derived from the numerical values in the following list, which are measures of the degree of destruction of the wood:

No attack	0
Very slight limnoria	5%
Slight limnoria	10%
Moderate limnoria	15%
Considerable limnoria	25%
Heavy limnoria	50%
Shipworm discarded	100%

An example of the figures for a set; four boards in the set, two showing slight limnoria attack, one showing moderate limnoria attack, and one attacked by shipworm:

$$10 + 10 + 15 + 100 = 135$$

$$100 \frac{(135)}{(4)} = 66.3 \text{ rating.}$$

(F.) The following abbreviations are used in the tables:

BA — Benzyl arsonic acid
BO — Brushed on
C — Creosote
DCX — Dichlorxylenol
DM — Diphenylaminechlorarsine
DNP — Dinitrophenol
EO — Triethanolamineoleate
F — Furfural
H — Hydrofuramide
LO — Light Oil
PDA — Phenyldichlorarsine
PG — Paris Green
RO — Residuum Oil
SFO — Santa Fe Oil
TPA — Triphenylarsine

Method of Installation of Marine Piling Test Pieces

Object: To determine resistance of impregnated test pieces to attack by marine borers.

Description: Two strings of 8 × 4 × ¾ inch pine test pieces, after removal from water, showing

a. Supporting cable, ⅜ inch, threaded through screw-eyes in test pieces.
b. Wire, $\frac{1}{16}$ inch, nailed to ends of test pieces to keep them separated.
c. String of test pieces as removed.
d. After inspection and ready for reinstallation, with new bait pieces and controls.

Project: F 92, Marine Piling.

Dates: Installed at Beaufort, N. C. by Research Division, April 13, 1931. Photographed at Beaufort, N. C., October 5, 1931.

Table 1

Inspection Results on Impregnated Test Pieces

Set No.	Vehicle	Toxic	No. Installed	No. Attacked	Limoria	Shipworm	Discarded	Inspection Rating 1930	1931	1932	Lb./cu.ft.
125	C	-	2	2	2	2	2	100	92.5	0	17.1
126	C	-	2	2	2	0	0	100	100	90.0	24.6
127	C	-	2	2	2	0	1*	100	100	90.0	22.3
128	C	-	2	2	2	1	1	100	90.0	42.5	20.9
129	C	-	2	2	2	0	0	100	95.0	90.0	24.2
130	C	-	2	2	2	0	0	100	97.5	92.5	27.3
131	C	-	2	2	2	0	0	100	95.0	87.5	19.9
132	C	2% F	2	2	2	0	0	100	92.5	85.0	17.0
133	C	2% F	2	2	2	2	2	100	97.5	0	18.0
134	C	2% F	2	2	2	0	0	100	100	92.5	17.2
135	C	2% F	2	2	2	0	0	100	100	90.0	17.4
136	C	2% F	2	2	2	1	1	100	100	47.5	19.1
137	C	2% F	2	2	2	1	1	100	95.0	42.5	19.5
138	C	2% F	2	2	2	0	0	100	100	90.0	17.9
139	C	2% F	2	2	2	0	0	100	100	90.0	23.8
140	C	1/2% EO	2	2	2	0	0	100	100	87.5	27.2
141	C	1/2% EO	2	2	2	0	0	100	95.0	87.5	21.3
142	C	1/2% EO	2	2	2	0	0	100	100	90.0	17.1
143	C	1/2% EO	2	2	2	0	0	100	100	90.0	21.0
144	C	1/2% EO	2	2	2	0	0	100	100	90.0	19.4
145	C	1/2% EO	2	2	2	0	0	100	100	90.0	23.0
146	C	1/2% EO	2	2	2	0	0	100	100	87.5	20.0
147	C	1/2% EO	2	2	2	0	0	100	100	95.0	26.6
148	C	2% DM	1	1	1	0	0	100	100	90.0	25.2
149	C	2% DM	1	1	1	1	1	100	90.0	0	16.1
150	C+10% F	2% DM	1	1	1	0	0	100	100	95.0	19.8
151	C+10% F	2% DM	1	0	0	0	0	100	100	100	25.2
152	C+10%F+NH_3	2% DM	2	2	2	0	0	100	100	90.0	31.6
153	C+10%F+NH_3	2% DM	2	2	2	0	0	100	97.5	90.0	20.9
154	C+10%F+NH_3	2% DM	2	2	2	0	0	100	100	92.5	23.9
155	C+10%F+NH_3	2% DM	2	0	0	0	0	100	100	100	30.2
156	F+NH_3	2% DM	2	2	2	0	1*	100	100	62.5	29.4
157	F+NH_3	2% DM	2	2	2	0	0	100	100	85.0	28.3
158	F+NH_3	2% DM	2	2	2	0	1*	100	92.5	62.5	32.8
159	F+NH_3	2% DM	2	2	2	0	1*	100	100	85.0	27.6
160	C-BO	9.7% Cl_2	2	2	2	2	2	100	0	0	3.8
161	C-BO	9.7% Cl_2	2	2	2	2	2	100	90	0	3.5
162	C-BO	21.5% Cl_2	2	2	2	2	2	100	85	0	2.7
163	C-BO	21.5% Cl_2	2		2	2	2	97.5	87.5	0	2.8
164	C-BO	41% Cl_2	2	2	2	2	2	100	0	0	2.7
165	C-BO	41% Cl_2	2	2	2	2	2	100	90	0	2.8

Table 1 cont'd...

Set No.	Vehicle	Toxic	No. Installed	No. Attacked	Limoria	Shipworm	Discarded	Inspection Rating 1930	1931	1932	Lb./cu.ft.
166	C-BO	Cu(Colloidal)	2	2	2	2	2	100	37.5	0	3.2
167	C-BO	Cu(Colloidal)	2	2	2	2	2	100	82.5	0	2.9
168	C-BO	-	2	2	2	2	2	95	0	0	2.0
169	C	2% DCX	2	1	1	0	0	100	100	95.0	24.1
170	C	2% DCX	2	2	2	0	0	100	100	90.0	21.1
171	C	4% DCX	2	2	2	1	1	100	100	45.0	21.5
172	C	4% DCX	2	2	2	0	0	100	100	82.5	16.6
173	C	6% DCX	2	1	1	0	0	100	97.5	95.0	19.8
174	C	6% DCX	2	2	2	0	0	100	97.5	92.5	21.2
175	LO	3% DCX	2	2	2	2	2	95.0	85.0	0	12.0
176	LO	3% DCX	2	2	2	2	2	100	85.0	0	10.0
177	LO	5% DCX	2	2	2	2	2	95.0	80.0	0	13.4
178	LO	5% DCX	2	2	2	2	2	97.5	45.0	0	13.4
179	C	4 1/2% Cl_2	2	2	2	2	2	100	100	0	16.5
180	C	4 1/2% Cl_2	2	2	2	2	2	100	100	0	12.1
245	C	-	4	4	3	1	1		97.5	67.5	21.9
246	C	1% TPA	4	2	2	0	1*		100	95.0	18.8
247	C	2% TPA	4	4	4	1	1		97.5	66.3	16.9
248	C	3% TPA	4	4	4	1	1		97.5	66.3	17.1
249	C-235	-	4	4	4	0	1*		98.8	87.5	16.1
250	C-235	1% TPA	4	2	2	0	1*		100	93.4	16.1
251	C-235	2% TPA	4	4	4	1	1		96.3	67.5	14.4
252	C-235	3% TPA	4	3	3	1	1		100	71.3	16.7
253	RO	-	4	4	4	4	4		22.5	0	7.8
254	RO	1% TPA	4	4	4	4	4		0		7.3
255	RO	2% TPA	4	4	4	4	4		0		6.2
256	RO	3% TPA	4	4	4	4	4		0		8.2
257	RO	1% $C_2H_4Cl_2$	4	4	4	4	4		0		8.1
258	RO	2% $C_2H_4Cl_2$	4	4	4	4	4		23.8	0	18.8
259	RO	2% $C_2H_4Cl_2$	4	4	4	4	4		0		8.9
260	RO	3% $C_2H_4Cl_2$	4	4	4	4	4		0		9.1
261	RO	3% $C_2H_4Cl_2$ 1% CH_3AsO	4	4	4	4	4		25.0	0	7.3
262	RO	3% $C_2H_4Cl_2$ 2% CH_3AsO	4	4	4	4	4		25.0	0	6.0
263	RO	3% $C_2H_4Cl_2$ 3% CH_3AsO	4	4	4	4	4		0		10.6
264	RO	1% CH_3AsO	4	4	4	4	4		0		8.2
265	RO	2% CH_3AsO	4	4	4	4	4		0		9.2
266	RO	3% CH_3AsO	4	4	4	4	4		0		10.7
267	LO	-	4	4	4	4	4		0		18.0
268	LO	1% CH_3AsO	4	4	4	4	4		25	0	15.6
269	LO	2% CH_3AsO	4	4	4	4	4		22.5	0	17.1
270	LO	3% CH_3AsO	4	4	4	4	4		25	0	17.3

Table 1 cont'd.....

Set No.	Vehicle	Toxic	No. Installed	No. Attacked	Limnoria	Shipworm	Discarded	Inspection Rating 1931	Inspection Rating 1932	Lb./cu.ft.
271	1 C+1RO	1% CH_3AsO	4	4	4	3	3	93.6	22.3	18.4
272	1 C+1RO	2% CH_3AsO	4	4	4	2	2	95.0	43.8	19.2
273	1 C+1RO	3% CH_3AsO	4	4	4	2	2	98.2	43.8	15.9
274	C	-	4	4	3	1	1	95.3	67.5	19.9
275	C	-	4	4	4	0	0	100	95.0	26.9
276	1 C+ 1Lo	-	4	4	4	1	1	93.8	70.0	19.6
277	3 C+2LO	1% BA	4	4	4	1	1	97.8	70.0	21.6
278	3 C+2LO	2% BA	4	4	4	2	2	72.5	45.0	19.5
279	3 C+2RO	3% BA	4	4	4	2	2	98.8	47.5	14.8
280	1 C+1RO	2% BA	4	4	4	3	3	98.8	23.8	18.3
281	2 C+1RO	1.5% BA	4	4	4	4	4	71.3	0	20.8
282	2 C+3RO	2% BA	4	4	4	3	3	73.8	23.8	15.0
283	1 C+1RO	-	4	3	3	2	2	72.5	47.5	20.1
284	1 C+1RO	1% TPA	4	4	4	3	3	72.5	23.8	19.7
285	1 C+1RO	2% TPA	4	4	4	0	0	97.5	91.3	21.2
286	1 C+1RO	3% TPA	4	4	4	3	3	72.5	23.8	19.1
287	1 C+1RO	1% DNP	4	4	4	2	2	75.5	47.5	18.3
288	1 C+1RO	2% DNP	4	4	4	3	3	98.2	22.5	21.2
289	1 C+1RO	3% DNP	4	4	4	4	4	68.8	0	31.6
290	1 C+1SFO	-	4	4	4	3	3	95.0	22.5	11.6
291	1 C+1SFO	1% PDA	4	4	4	4	4	97.5	0	19.2
292	1 C+1SFO	2% PDA	4	4	4	2	2	96.3	46.3	23.6
293	1 C+1SFO	3% PDA	4	4	4	1	1	96.3	68.8	22.5
300	C	-	4	3	3	1	1		71.3	21.2
301	C	-	4	3	2	1	1		71.3	17.7
302	1 C+1RO	-	4	2	1	1	1		73.8	19.0
303	1 C+1RO	-	4	3	2	1	1		72.5	20.0
304	RO	-	4	4	4	4	4		0	18.4
305	RO	-	4	4	4	4	4		0	27.2
306	RO	0.25% CH_3AsO	4	4	4	4	4		0	11.2
307	RO	0.5% CH_3AsO	4	4	4	4	4		0	19.7
308	RO	0.75% CH_3AsO	4	4	4	4	4		0	11.9
309	1 C+1RO	0.25% CH_3AsO	4	3	3	1	1		70.0	25.9
310	1 C+1RO	0.5% CH_3AsO	4	4	4	2	2		46.3	14.5
311	1 C+1RO	0.75% CH_3AsO	4	2	2	1	1		73.8	23.4
312	RO	0.25% C_6H_5AsO	4	4	4	4	4		0	17.2
313	RO	0.5% C_6H_5AsO	4	4	4	4	4		0	11.5
314	RO	0.75% C_6H_5AsO	4	4	4	4	4		0	13.4
315	1 C+1RO	0.25% C_6H_5AsO	4	4	4	1	1		67.5	23.4
316	1 C+1RO	0.5% C_6H_5AsO	4	4	3	2	2		45.0	22.5
317	1 C+1RO	0.75% C_6H_5AsO	4	4	4	2	2		46.3	17.2
318	RO	1% $C_2H_4Cl_2$	4	4	4	4	4		0	22.0
319	RO	2½% $C_2H_4Cl_2$	4	4	4	4	4		0	14.0
320	RO	5% $C_2H_4Cl_2$	4	4	4	4	4		0	17.4

Table 1 cont'd.....

Set No.	Vehicle	Toxic	No. Installed	No. Attacked	Limnoria	Shipworm	Discarded	Inspection Rating 1932	Lb./cu.ft.
321	1 C + 1 RO	1% $C_2H_4Cl_2$	4	8	5	1	1	71.3	22.2
322	1 C + 1 RO	2 1/2% $C_2H_4Cl_2$	4	4	4	2	2	46.3	19.5
323	1 C + 1 RO	5% $C_2H_4Cl_2$	4	4	3	3	3	22.5	16.5
324	RO	5% $C_2H_4Cl_2$ 1% DM	4	4	4	3	3	22.5	11.9
325	RO	5% $C_2H_4Cl_2$ 2% DM	4	4	4	1	2*	68.8	12.1
326	1 C + 1 RO	5% $C_2H_4Cl_2$ 1% DM	4	1	1	0	0	97.5	22.6
327	1 C + 1 RO	5% $C_2H_4Cl_2$ 2% DM	4	1	1	0	0	98.8	22.8
328	RO	1% H	4	4	4	4	4	0	10.9
329	RO	2% H	4	4	4	4	4	0	14.1
330	RO	3% $C_2H_4Cl_2$ 2% H	4	4	4	4	4	0	15.6
331	1 C + 1 RO	3% $C_2H_4Cl_2$ 1% H	4	2	2	2	2	50.0	20.4
332	1 C + 1 RO	3% $C_2H_4Cl_2$ 2% H	4	1	1	0	1*	98.8	24.7
333	H_2O 5% NH_4OH	1% PG	4	4	4	4	4	0	12.8
334	H_2O 5% NH_4OH	2% PG + F	4	4	4	4	4	0	18.9
335	H_2O 5% NH_4OH	2% PG + F	4	4	4	4	4	0	26.2
336	H_2O 5% NH_4OH	2% PG + F	4	4	4	4	4	0	11.4
337	RO	2% $C_2H_4Cl_2$	4	4	4	4	4	0	13.1
338	RO	1% Diphenyl	4	4	4	4	4	0	17.9
339	1 C + 1 RO	0.5% Diphenyl	4	1	1	1	1	75.0	23.0
340	1 C + 1 RO	1% Diphenyl	4	2	1	1	1	73.8	14.6
341	8 C + 2 RO		4	1	1	0	0	98.8	21.8
342	7 C + 3 RO		4	0	0	0	0	100	23.1
343	6 C + 4 RO		4	4	4	1	1	70.0	16.8
344	5 C + 5 RO		4	2	2	0	1*	96.3	18.9
345	4 C + 6 RO		4	2	1	1	1	73.8	25.4
346	3 C + 7 RO		4	2	1	1	0	73.8	25.8
347	2 C + 8 RO		4	4	3	2	2	47.5	15.2
348	8 C - 235 + 2 RO		4	0	0	0	0	100	21.2
349	7 C - 235 + 3 RO		4	2	2	0	0	97.5	22.4
350	6 C - 235 + 4 RO		4	1	1	1	1	75.0	26.8
351	5 C - 235 + 5 RO		4	4	3	3	3	22.5	17.8
352	4 C - 235 + 6 RO		4	3	3	1	1	71.3	18.1
353	3 C - 235 + 7 RO		4	3	3	2	2	48.8	18.8
354	2 C - 235 + 8 RO		4	4	4	2	3*	46.3	16.7
355	2.5 CuSO 2.1 $K_4Fe(CN)_6$		4	4	4	4	4	0	

* One test piece split for examination, no shipworm attack found.

DISCUSSION OF RESULTS

(A) Unimpregnated Baits and Controls.

The increased attack incited by bait pieces is illustrated by comparing the attack on similar test pieces with and without baits. Two hundred twenty-four (224) test pieces were compared, 112 with and 112 without baits. Forty-four per cent of the test pieces without baits showed attack, while 76 per cent of the test pieces with an attached bait were attacked. The practically complete destruction of all bait pieces and controls in one season shows the heavy infestation of borers in these waters. In most cases the crowded condition of the bait forces attack on the test piece. This is evident, after removing the bait, by the large number of nicks in the test piece.

(B) Test Pieces.

Two sets, No. 151 and 155, subjected to attack for 3 seasons showed neither limnoria nor shipworm attack. The vehicle used in No. 151 was creosote + 10 per cent furfural, to which 2 per cent DM was added as the toxic, and in No. 155 was the same with a second treatment with ammonia. The addition of the furfural probably increased the solubility of the DM in creosote.

Since toxics vary considerably in water solubility, the possibility that this variation might be the determining property was investigated. In one set methylarsenious oxide, which is very soluble in water, was used; in another set, phenylarsenious oxide, which is very slightly soluble, was used. Both are soluble in residuum oil, which was used as a vehicle, at least to the extent to which they were added. None of these solutions was of any value in protecting wood.

A comparison of the average of the rating values of test pieces impregnated with creosote, light oil and residuum oil, with and without toxics, is made in Table 2. The relation between rating and lb./cu. ft. of creosote is shown in Table 3, and between creosote and creosote + toxics, in Table 4.

Table 2

Comparison of Test Pieces Impregnated with Creosote, Residuum Oil and Light Oil

	No. Test Pieces	*Attack*		*Average Rating 1932*	*Av. Number lb./cu. ft.*
		L	*S*		
Creosote	34	29	7	72.8	21.9
Residuum Oil	12	12	12	0.0	17.8
Light Oil	4	4	4	0.0	18.0
Creosote + TPA	12	10	2	75.8	17.6
Residuum Oil + TPA	12	12	12	0.0	7.2
Creosote + DCX	12	10	1	82.5	20.7
Light Oil + DCX	8	8	8	0.0	12.2

These comparisons show that residuum oil and light oil have very little value, compared to creosote, even when reinforced by toxics. Residuum oil is much more difficult to inject in wood than creosote and the less number of pounds per cubic foot impregnated reduces the amount of toxic taken up by the wood.

Table 3

Relation Between lb./cu. ft. of Creosote and Rating

Date Installed	*No.*	*Lb./cu. ft.*	*Rating*
4– 3–30	125	17.1	0
"	131	19.9	87.5
"	128	20.9	42.5
"	127	22.3	90.0
"	129	24.2	90.0
"	126	24.6	90.0
"	130	27.5	92.5
4–13–31	274	19.9	67.5
"	275	26.9	95.0
4– 5–32	300	17.7	71.3
"	301	21.2	71.3

TABLE 4

Comparison of Test Pieces Impregnated with Creosote and with Creosote Plus Toxics

	No. Test Pieces	*Attack*		*Average Rating 1932*	*Av. Number lb./cu. ft.*
		L	*S*		
Creosote alone	34	29	7	72.8	21.9
Creosote + toxic	26	22	4	77.3	19.4

This comparison indicates a slight advantage in adding toxic to creosote, but this is not believed to be significant on account of the short time of the test. These results have forced the conclusion that to get reliable results on toxics quickly, it is necessary to use some vehicle other than creosote. For these reasons the Chemical Warfare Service is increasing the use of residuum oil as the toxic carrier in this work.

Conclusions

1. No definite conclusions can be drawn as to the value of creosote reinforced with toxics as compared with creosote alone, since the test pieces have been exposed for too short a time, in no case over three years.

2. Due to the long life of creosote alone, it is believed advisable to test the effectiveness of toxics in some vehicle having little or no protective value alone, such as a petroleum residuum oil.

"SEA ACTION COMMITTEE"

INSTITUTION OF CIVIL ENGINEERS—ENGLAND

The 13th Interim Report published in June 1932 was received.

Attention has been called in previous abstracts to the tests of corrosion of metals being carried on by this committee and the fact that some rather generally accepted ideas, especially as to the resistance of the so-called "irons", were not confirmed by these tests. The report under discussion contains detailed reports on the specimens exposed above high tide, in the tidal range and below low tide at Halifax, N. S. and Auckland, N. Z. for ten years. The results of both the five and ten year laboratory inspections so far as indicated by loss in weight are shown in the following table.

LOSS IN WEIGHT PER 1000 SQ. C. M.

		HALIFAX						AUCKLAND					
		AERIAL		WET & DRY		IMMERSED		AERIAL		WET & DRY		IMMERSED	
METAL	CONDITION	5 Yr. GM	10 Yr. GM	5 Yr. GM	10 Yr. GM	5 Yr. GM	10 Yr. GM	5 Yr. GM	10 Yr. GM	5 Yr. GM	10 Yr. GM	5 Yr. GM	10 Yr GM
1. Low Moor - W1	Cleaned	119	198	165	321	421	965	219	425	140	253	313	487
2. Swedish Charcoal Iron	"	119	251	264	406	422	1083	267	588	136	309	314	459
3. Armco Iron	"	117	182	304	445	445	1067	332	591	212	310	332	438
4. Mild Steel - Low Mn High S&P	With Scale	137	220	522	600	383	877	262	945	108	116	246	583
5. Mild Steel-0.70% Mn	" "	103	189	331	377	371	772	150	399	123	107	347	618
6. " " " "	Cleaned	52	162	214	308	364	822	164	343	231	290	306	655
7. Medium Carbon Steel low S&P	With Scale	84	168	217	317	371	905	172	399	118	210	341	569
8. " " " " " "	Cleaned	61	162	172	261	421	874	136	244	214	302	456	782
9. 0.40% Carbon Steel	With Scale	82	162	323	379	362	815	203	378	104	169	377	537
10. Mild Steel 0.635% Cu	" "	53	117	144	287	344	760	79	214	63	137	317	582
11. " " 2.185% Cu	" "	39	89	162	340	351	890	52	111	103	135	308	624
12. 13.57% Chromium Steel	" "	9	16	50	52	216	460	15	22.2	50	135	230	327
13. 3.75% Nickel Steel	" "	2.3	61	48	137	336	649	44	101	71	111	258	441
14. 26.55% Nickel Steel	" "	2.3	7.3	39	71	266	464	6	12.3	24	38	138	197
15. Hot Blast Cast Iron	As Cast	3.5	117	27	72	253	723	16	169	51	81	252	509
16. Cold Blast Cast Iron	As Cast	5.6	9.4	18	76	217	635	9	82	32	54	228	550

		LOSS IN WEIGHT PER 1000 SQ. C. M.											
		AERIAL				ALT. WET AND DRY				IMMERSED			
		HALIFAX		AUCKLAND		HALIFAX		AUCKLAND		HALIFAX		AUCKLAND	
METAL	CONDITION	5 Yr. GM	10 Yr. GM	5 Yr. GM	10 Yr. GM	5 Yr. GM	10 Yr. GM	5 Yr. GM	10 Yr. GM	5 Yr. GM	10 Yr. GM	5 Yr. GM	10 Yr. GM
1. Low Moor Wrought Iron	Cleaned	119	198	219	425	165	321	140	250	421	965	313	437
2. Swedish Charcoal Iron	"	119	251	267	583	264	406	186	309	422	1083	314	459
3. Armco Iron	"	117	182	332	591	304	445	212	310	449	1067	332	482
4. Mild Steel-Low MN. High S & P	With Scale	137	220	262	945	522	609	102	116	383	877	346	503
5. " " -0.70% Mn	" "	103	187	150	399	331	377	123	197	371	772	347	613
6. " " " "	Cleaned	59	162	164	343	214	308	231	290	364	732	386	655
7. Medium Carbon Steel Low S & P	With Scale	84	168	172	399	217	317	118	210	371	905	341	569
8. " " " " "	Cleaned	61	162	136	244	172	261	214	302	421	374	456	782
9. 0.40% Carbon Steel	With Scale	82	162	203	378	323	379	104	160	362	815	377	537
10. Mild Steel - 0.635% Cu	" "	53	117	79	214	144	287	63	137	344	760	317	582
11. " " - 2.185% Cu	" "	39	89	52	111	162	340	103	135	351	896	308	624
12. 13.5% Chromium Steel	" "	9	16	15	22.2	50	52	59	135	216	460	210	327
13. 3.75% Nickel Steel	" "	23	61	44	101	48	137	71	111	336	649	258	441
14. 36.55% " "	" "	2.3	7.3	6	14.3	39	71	24	35	266	464	138	197
15. Hot Blast Cast Iron	As Cast	3.5	117	16	169	27	72	55	81	253	723	250	309
16. Cold Blast Cast Iron	As Cast	5.6	9.4	8	82	19	76	32	54	217	635	228	550

It will be seen that there is considerable difference in the relative value of the different metals and alloys depending on the exposure but there seems to be no question as to the superiority of the high nickel steel under all conditions of exposure except for the cast irons under some conditions. The three wrought irons tested were distinctly inferior to the mild steels under the same conditions and still more corroded than the copper steels with the single exception of the 10 year test at Auckland.

Water and atmospheric conditions are responsible for the greater corrosion shown at Auckland than at Halifax.

The report also contains photographs of many specimens and information as to the kind of corrosion present in the various test pieces.

No new experiments were started with impregnated timber, but a progress report is made on the napthalene tests initiated in 1930. These test blocks which were installed for test at Kilindini, Kenya Colony and Mauritius were treated by the Bethell process as follows:—

1. Crude naphthalene.
2. ⅔ crude naphthalene, ⅓ creosote.
3. ⅓ crude naphthalene, ⅔ creosote.
4. Creosote.
5. Creosote followed by naphthalene, with a view to prevent the leaching out of creosote.
6. Crude naphthalene plus 3 per cent. D.M. (chlorodihydrophenarsazine).

One hundred and twenty blocks (twenty impregnated with each mixture) were sent to Kilindini, and a similar set was sent to Mauritius. A few blocks have been returned after an exposure of 12–18 months. They indicate the unexpected conclusion, which is subject to confirmation by later examinations, that mixtures 2 and 3 are less effective than either 1 or 4. The reason for this is apparently to be sought in the less effective penetration of mixtures 2 and 3, of which on the average smaller quantities were absorbed than of substances 1 and 4. Crude naphthalene penetrates well and crystallizes out inside the wood, where it is readily recognized after the block has been split. While it undoubtedly confers some protection, naphthalene appears however to be less efficient than creosote. Since creosote alone has so far afforded full protection, no conclusions can be drawn regarding treatment 5; however, analysis after a prolonged exposure may show that tar acids are retained better when creosoting is followed by treatment with naphthalene. In the mixture 6 naphthalene is chiefly interesting as a vehicle for D.M., and this mixture has, during the short exposure so far investigated, protected the timber as completely as creosote.

Tests of block impregnated with fuel oil as a carrier are somewhat similar to those being carried on by this committee with the specimens prepared by the Chemical Warfare Service. They are reported as follows:

The eighth series of timber blocks were prepared to test fuel-oil as a vehicle for D.M. Four mixtures were used, namely: creosote alone, creosote plus 3 per cent of D.M., fuel-oil alone, and fuel-oil plus the same percentage of D.M. Thirty blocks of

each kind, making a set of 120, were exposed at each of three stations—Bermuda, Jamaica and Takoradi—in June and November, 1929, and January, 1930 respectively. While many blocks have disappeared, particularly at Takoradi, those which have been returned from Bermuda and Jamaica definitely show that the fuel-oil by itself has had no protective action, and that fuel-oil plus 3 per cent. of D.M. has protected, so far completely, the parts of the timber to which it has penetrated.

Creosote, both alone and with D.M. affords complete protection for several years, and therefore these tests will not allow any beneficial effect of adding D.M. to creosote to be observed for a long time. The particular fuel-oil used penetrated the blocks very badly, usually only a small part of the block being impregnated. If the fuel-oil contains D.M. that part alone is fully protected: there is a sharp line of demarcation, in contrast to the gradual transition observed with creosote. The non-impregnated portion is generally riddled with Teredo channels, right up to the line of demarcation, where they abruptly stop, showing the deterrent effect of D.M. even on the vigorous adult borer.

The main problem is to make the fuel-oil penetrate throughout the block. This difficulty is already apparent from the increases in weight on impregnation of various test-blocks recorded by Professor Dixon. Generally this increase with fuel-oil was about one-fifth of that with creosote, and a good deal of the fuel-oil was moreover quite near the surface. Crude naphthalene, a hydro-carbon, and Pintsch gas tar, apparently consisting also largely of hydro-carbons, penetrate completely, as does creosote, and it does not seem impossible that a variety of fuel-oil may be found which does penetrate satisfactorily. A suitable vehicle for D.M. would be very useful. It must be cheap, particularly since the price of creosote, which is quite efficient by itself, has fallen considerably since the Committee's investigations began; crude naphthalene costs about as much as creosote; and the only solution would appear to be in a natural oil, and possibly in some method of drying wood more completely.

In general the failure of large creosoted timbers is probably to be attributed to inadequate impregnation, or damage to the impregnated surface layer, rather than to inefficiency of the creosote.

The report also contains information regarding the deterioration of reinforced concrete in sea water and tests of the resistance of various native timbers and greenheart to marine borer attack at Rangoon, Burma.

These timber tests were started in 1922 and are reported in "Burma Forest Bulletin No. 28, Rangoon, 1932" but the period of exposure of the specimens reported was only from one to two years. All untreated timbers were attacked but no creosoted specimens including greenheart showed much attack.

SUMMARY

The Panama tests show that several of the tropical timbers under test have high resistance, especially those containing silica.

Series No. 1 Chemical Warfare Service have now been under test for 8 years.

The copper carbonate treatment showed considerable resistance but all pieces have been attacked and some of them destroyed.

The fuel oil D.M. and phenydichlorarsene treatment also showed resistance but again these pieces are practically all gone and were quickly attacked by limnoria.

The creosote D.M. pieces are still under test and none of them with the exception of one at Charleston, S. C. has been seriously damaged.

The test on Series No. 2 of the Chemical Warfare Service has been far too short a time to give final results but the three petroleum treatments all show greater or less attack.

The attack on the San Francisco Bay specimens is still too light after 10 years to give any indication as to the relative value of the different creosotes.

The report of the "Sea Action Committee" of the Institution of Civil Engineers does not show results very much different from those of this committee and no very definite conclusions can be drawn.

Conclusion

Your Committee recommends that this report be accepted as information.

Appendix D

(4) SPECIFICATIONS FOR TREATMENT OF AIR-SEASONED DOUGLAS FIR

R. S. Belcher, Chairman; F. D. Mattos, Vice-Chairman, Sub-Committee; H. R. Duncan, W. R. Goodwin, G. R. Hopkins, R. S. Hubley, H. E. Horrocks, A. J. Loom, G. P. MacLaren, Clyde Osborne, L. J. Reiser, Dr. Hermann von Schrenk, C. M. Taylor.

Last year, as a part of its report, your Committee presented as information Specifications covering the Treatment of Air-Seasoned Douglas Fir, which appear on Pages 478 to 482 of Vol. 34, recommending they be referred to other interested committees for consideration and criticism with a view to later presenting the specifications for inclusion in the Manual. Committee III—Ties, and Committee VII—Wooden Bridges and Trestles, were asked to collaborate, particularly as to the practice of incising ties and bridge timbers as covered by the Specifications.

These committees have approved the specifications as they appear in the Proceedings, and your Committee now present the specifications for inclusion in the Manual.

SPECIFICATIONS FOR THE TREATMENT OF AIR SEASONED DOUGLAS FIR

Material

Material for treatment shall be in accordance with the specifications of this Association. Special attention, however, is directed to the peeling and sapwood requirements of round timbers which have direct bearing on the quality of treatment which may be secured.

Peeling and Sapwood Requirements of Round Timbers

All round timbers shall be thoroughly peeled before treatment. No piece shall be considered thoroughly peeled unless all the rough bark and at least 80 per cent of the inner bark shall have been removed. In no case shall any piece of inner bark be over ¾ in. wide or over 8 in. long, and there shall be 1 in. of clean wood surface between any two such strips. Should the strips of inner bark remaining on the pole be less than ¾ in. wide, the clear space required between any two such strips may be proportionally less than 1 in. No circumference may have more than 20 per cent of its surface covered with inner bark, although the entire surface of the pole may contain less than the allowable 20 per cent.

Piling and poles shall have sapwood of a minimum thickness of 1 in. at the butt end.

Seasoning

Douglas fir shall be air seasoned under conditions in accordance with the recommended practice of this Association. Since the rate of seasoning varies with the latitude, time of year, the exposure, and the climatic peculiarities of the season, it is essential to establish the seasoning period for each class of Douglas fir for any particular locality. The seasoning period shall be of sufficient length to reduce the moisture content of the marginal two inches of any cross-section of round or sawed timbers to 20 per cent, or less, of its oven dry weight. In material less than 4 in. in thickness, entire cross-sections shall be considered.

Adzing, Boring and Framing

Insofar as practicable, all adzing, boring and framing of all kinds shall be done before treatment to minimize subsequent cutting through the treated shell and exposure of untreated wood.

Incising

All sawed Douglas fir shall be incised two sides and two edges, using incisor teeth not more than $\frac{5}{32}$ in. thick. Incisions ¾ in. in depth are recommended for all sawed fir six inches thick or over, and ½ in. in depth in sides and ¾ in. in the edges of all sawed fir less than 6 in. and more than 2 in. in thickness. Incising of material less than 2 in. in thickness is not recommended. The pattern recommended for the placing of the incisions is shown by Fig. 1.

Grouping for Treatment

It is essential that Douglas fir be grouped properly in order that successful treatment may be obtained. Any charge shall be confined to pieces of approximately equal sapwood and moisture content, into which approximately equal quantities of preservative can be injected, and so separated as to insure contact of preservative with all surfaces.

Treatment

General

The ranges of pressure, temperature, and time duration shall be controlled so as to result in maximum penetration by the quantity of preservative injected, which shall permeate all the sapwood, and as much of the heartwood as practicable. The vacuum requirements stipulated are those of sea level and necessary corrections shall be made for altitude.

Retention of Preservative

No charge shall contain less than 90 per cent nor more than 120 per cent of the quantity of preservative that may be specified; but the average retention of the preservative by the material treated under any contract or order shall be at least 100 per cent of the quantity specified.

The amount of preservative retained shall be calculated on the basis of preservative at 100° Fahr., from readings of working tank gages, or scales, or from weights before and after treatment of loaded trams on suitable track scales, with a correction for difference in moisture content, and checked as may be desired by the purchaser's representative.

Determination of Penetration

Penetration shall be determined by sampling material in each charge, as may be desired by the purchaser's representative. Any holes which may be bored shall be filled with tight-fitting treated plugs.

Plant Equipment

Treating plants shall be equipped with the thermometers and gages necessary to indicate accurately and record the conditions at all stages of treatment, and all equipment shall be maintained in condition satisfactory to the purchaser. The apparatus and chemicals necessary for making analyses and tests required by the purchaser shall also be provided by plant operators and kept in condition for use at all times.

Preservative

The preservative used shall conform to one of the following standards of this Association.

Creosote, classes one, two or three.
Creosote-Coal Tar Solution.
Zinc Chloride.

Amount of Preservatives to be Used—Douglas Fir for General Construction

(a) Creosote

Full Cell Process, not less than 10 lb. per cu. ft. of timber or to refusal.
Rueping Process, not less than 6 lb. per cu. ft. of timber.
Lowry Process, not less than 6 lb. per cu. ft. of timber.

(b) Zinc Chloride

Not less than ½ lb. of dry salt per cu. ft. of timber.

(c) Creosote-Zinc Chloride

Not less than 2 lb. of creosote and ½ lb. dry zinc chloride per cu. ft. of timber.

Amount of Preservative to be Used—Douglas Fir for Use in Salt Water

Creosote—Not less than 12 lb. per cu. ft. of timber.

Other preservatives are not recommended for this class of service.

Treating Operations

Ties, Structural Timbers and Lumber of All Sizes

Creosote Treatments

Heating

Preliminary to the pressure period, it may be found advantageous to heat the air-seasoned timber. When this is the case, the treating cylinder may be filled with the preservative heated to a temperature of 180° F. to 200° F. and held to as nearly 200° F. as possible for not more than 6 hr.

Full Cell Process

Following the heating period, or as the first stage of the treatment, if no heating period used, a vacuum of not less than 22 in. shall be speedily created and maintained for a period of not less than 30 min. so that the timber may be as free from air as practicable. Without breaking the vacuum, the treating cylinder shall be filled with preservative heated to a temperature of 180° F. to 200° F. The pressure shall then be gradually raised to a maximum of 100 lb. per square inch over a period of not less than 30 min. nor more than 1 hr. and 30 min., and maintained until the quantity of preservative required to insure the final retention stipulated is injected into the wood, or failing this, until the purchaser's representative is satisfied that the largest volumetric injection that is practicable has been obtained. In no case, however, shall the period of maximum pressure exceed 12 hr. The temperature of the preservative during the pressure period shall not be less than 180° F. nor more than 200° F. and shall average at least 190° F.

After pressure is completed, the cylinder shall be emptied speedily of preservative and a vacuum of at least 22 in. promptly created and maintained until the timber can be removed from the cylinder free of dripping preservative.

Rueping Process

Following the heating period, or as the first stage of the treatment, if no heating period is used, the timber shall be subjected to air pressure of sufficient intensity and

duration to provide, under a vacuum, the ejection of surplus preservative and to insure proper distribution and maximum penetration of the stipulated number of pounds of preservative per cubic foot of wood.

The preservative shall be introduced between 180° F. and 200° F., the pressure being maintained constant until the cylinder is filled with preservative. The pressure shall then be gradually raised over a period of not less than 30 min. nor more than 1 hr. and 30 min. to a minimum of 125 lb. per square inch and maintained within a maximum of 175 lb. per square inch, but in no case shall exceed 100 lb. more than the air pressure used, until there is obtained the largest practicable volumetric injection that can be reduced to the required retention by a quick high vacuum, or, failing this, until the purchaser's representative is satisfied that the largest volumetric injection that is practicable has been obtained. In no case, however, shall the period of maximum pressure exceed 12 hr. The temperature of the preservative during the pressure period shall be not less than 180° F., nor more than 200° F., and shall average at least 190° F.

After pressure is completed, the cylinder shall be emptied speedily of preservative and a vacuum of at least 22 in. promptly created and maintained until the timber can be removed from the cylinder free of dripping preservative. As an alternative, both additional heat and vacuum may be applied as follows. After pressure is completed and before removal of preservative from the cylinder, the preservative surrounding the timber may be heated to a maximum of 220° F., the steam to be turned off the heating coils immediately the maximum temperature is reached. The preservative shall then be removed from the cylinder and a vacuum applied as specified above.

Lowry Process

Following the heating period, or as the first stage of the treatment, if no heating period is used, the treating cylinder shall be filled with the preservative, heated to a temperature of 180° F. to 200° F. Pressure shall then be gradually raised to a maximum of 100 lb. per square inch over a period of not less than 30 min. nor more than 1 hr. and 30 min. and maintained until there is obtained the largest volumetric injection practicable that can be reduced to the required retention by quick high vacuum, or, failing this, until the purchaser's representative is satisfied that the largest volumetric injection that is practicable has been obtained. In no case, however, shall the period of maximum pressure exceed 12 hr. The temperature of the preservative during the pressure period shall not be less than 180° F. nor more than 200° F. and shall average at least 190° F.

After pressure is completed, the cylinder shall be emptied speedily of preservative and a vacuum of at least 22 in. promptly created and maintained for not less than 30 min. until the quantity of preservative injected is reduced to the required retention and the timber can be removed from the cylinder free of dripping preservative. As an alternative, both additional heat and vacuum may be applied as follows. After pressure is completed, and before removal of preservative from the cylinder, the preservative surrounding the timber may be heated to a maximum of 220° F., the steam to be turned off the heating coils immediately the maximum temperature is reached. The preservative shall then be removed from the cylinder and a vacuum applied as specified above.

Zinc Chloride Treatment

The treating solution shall be no stronger than necessary to obtain the required retention of preservative with the largest volumetric absorption practicable and shall be thoroughly mixed before use.

The timber shall first be subjected to a vacuum of not less than 22 in. for at least 30 min. before the preservative is admitted to the cylinder. The preservative shall be

introduced between 180° F. and 200° F., without breaking the vacuum until the cylinder is filled. The pressure shall then be gradually raised to a maximum of 100 lb. per square inch over a period of not less than 30 min. nor more than 1 hr. and 30 min. and maintained until the quantity of preservative required to insure the final retention stipulated is injected into the wood, or until less than 2 per cent of the total quantity required has been injected during the latter half of one hour throughout which the rate of injection has persistently decreased while the pressure has been held continuously at the maximum. In no case, however, shall the period of maximum pressure exceed 12 hr. The temperature of the preservative during the pressure period shall not be less than 180° F. nor more than 200° F. and shall average at least 190° F.

After the pressure is completed, the cylinder shall be speedily emptied of preservative and a vacuum promptly created and maintained until the timber can be removed from the cylinder free of dripping preservative.

Creosote-Zinc Chloride Treatment

The preservative mixture shall be composed of the volumetric proportions of creosote and zinc chloride solution of the necessary strength required to obtain the stipulated retention with the largest volumetric injection that is practicable, and shall be agitated in the working tank and treating cylinder so as to insure thorough mixing before and while the cylinder is being filled with preservative and while the preservative is being injected into the timber.

The timber shall first be subjected to a vacuum of not less than 22 in. for at least 30 min. before the preservative is admitted to the cylinder.

The treating cylinder shall be filled with the mixture of preservatives heated to a temperature of 180° F. to 200° F. without breaking the vacuum. The pressure shall then be raised to a maximum of 100 lb. per square inch over a period of not less than 30 min. nor more than 1 hr. and 30 min. and maintained until the quantity of preservative required to insure the final retention stipulated is injected into the wood, or until less than 2 per cent of the total quantity required has been injected during the latter half of one hour throughout which the rate of injection has persistently decreased, while the pressure has been held continuously at the maximum. In no case, however, shall the period of maximum pressure exceed 12 hr. The temperature of the preservative during the pressure period shall not be less than 180° F. nor more than 200° F. and shall average at least 190° F.

After pressure is completed, the cylinder shall be emptied speedily of preservative and a vacuum promptly created and maintained until the timber can be removed from the cylinder free of dripping preservative.

Treating Operations

Piles and Poles

Specifications for treating operations covering piles and poles are the same as those covering ties, structural timber and lumber, except that the period of maximum pressure of preservative in all treatments may be held to a limit of 16 hr. instead of 12 hr. as in the treatments of sawed timber.

Conclusion

Your Committee recommends the adoption of the above specification for publication in the Manual.

Appendix E

(5) DESTRUCTION BY TERMITES AND POSSIBLE WAYS OF PREVENTION

Dr. Hermann von Schrenk, Chairman, Sub-Committee; Wm. G. Atwood, C. C. Cook, L. H. Harper, G. R. Hopkins, F. D. Mattos, L. B. Shipley, W. A. Summerhays, C. M. Taylor.

The Committee on Termites has kept track of developments with reference to termites during the last year. These insects have been reported as extremely active from many points in the United States. The newspapers have given this subject wide publication, particularly at such points as Elkhart, Ind., where the termites attacked a school building, and also in the district about New York City and on Long Island. With a wider understanding of the type of destruction which they bring about, more and more people have watched for them.

In a brief report of this character, it is impossible to give all the points where serious attacks have been reported. It is of interest so far as the railways are concerned to note that the Committee has received one report of an attack on untreated piling in bridges in Louisiana, and, from the same state a report together with actual samples of their activity in a tie-seasoning yard. The insects built their tunnels across creosoted stringers and were beginning to attack the lowest tier of untreated oak ties when they were fortunately discovered. It goes to show that, particularly in the Southern country, all untreated wood should be very carefully watched and whenever the earthen tunnels appear, prompt positive measures should be taken.

One of the outstanding investigations of the year was undertaken during the past summer by the R.C.A. Communications, Inc., of New York. This test was undertaken in cooperation with the United States Bureau of Entomology for the purpose of testing the effect of various soil poisons. This test is considered by the Committee of such importance that a detailed statement regarding same follows herewith. The Committee expresses its appreciation to R. T. Rossi, Chief Engineer of the R.C.A. Communications, Inc., and to Dr. Thomas E. Snyder of the Bureau of Entomology for the following statement:

EXPERIMENTS WITH CHEMICALS FOR PROLONGING THE LIFE OF POLES BY POISONING THE SURROUNDING SOIL

In cooperation with the R.C.A. Communications, Inc., of New York, the Bureau of Entomology of the U.S. Department of Agriculture began a series of soil poisoning experiments during the latter part of August and first part of September 1933, at Riverhead, L.I. Here the western red cedar poles were being damaged by subterranean termites. These poles mostly had been set in 1928 and had been given a brush treatment with "Carbosota" before placement. The soil which is Lakewood sand, is generally infested with termites.

In 1932 varying amounts of the sapwood of these poles had shaved or chipped away below the ground line. These areas of the poles had then been sprayed with "Carbosota".

In August and September, 1933, the earth was removed about each pole to the depth fo 30 in. and then the poison was poured or layered in the soil near the pole to the ground line. One gallon of liquid was poured in trenches every 6 in. and the soil returned about the pile; where powder or crystals were used it was placed in trenches every 10 in. Using 10 men per 10 hour-day, 3 miles of pole line or 100 poles were treated per day.

Thirty different applications were placed under test on 281 poles using 28 different chemicals. Untreated infested check poles are included in this experiment. As a rule, 10 poles were treated with each poison; the poles are marked and their location plotted on a map.

The following chemicals are under test:

Compound	*Amount Used Per Pole*
Sodium arsenite—10 per cent solution	5 gallons
" " —dry	5 pounds
Copper arsenite	5 pounds
Arsenic trioxide	5 pounds
Lead arsenate	4 pounds
Anaconda paste	10 pounds
Zinc Meta Arsenite	5 pounds
"Antimite"	5 pounds
Sodium fluosilicate	5 pounds
Copper sulphate	5 pounds
"Hallowax" No. 1011	5 pints
Carbon bisulphide—35 per cent miscible (6 quarts to 50 gallons of water)	5 gallons
Orthodichlorobenzene	5 gallons
Paradichlorobenzene	5 pounds
Pyridine commercial No. 2	5 gallons
Crude naphthalene	5 pounds
Crank case oil	5 gallons
" " "	10 gallons
Coal tar creosote—Grade 1	5 gallons
Coal tar creosote 50 per cent, and "Panoline" (petroleum) 50 per cent	5 gallons
Coal tar creosote 1 part, kerosene oil 3 parts	5 gallons
"Reilly Transparent Penetrating Creosote"	5 gallons
"Aczol" (10 per cent solution by volume)	2 gallons
"Terminix"	5 gallons
"Creol"	5 gallons
"Cabinol"	5 gallons
Salt	10 pounds
Chlorinated lime (30 per cent chlorination)	5 pounds
Flake naphthalene	2½ pounds
Zinc chloride	5 pounds

The test which the Committee reported last year which was installed in Florissant, Mo., in 1932, is still in progress. Possibly because of the extremely dry and hot summer, there was little or no termite attack indicated on the test pieces, so it was thought advisable to let the stakes remain for another year, at which time it is hoped that the Committee will be able to make a progress report.

Another series of tests of outstanding value are those undertaken by the Bureau of Entomology, under the direction of Dr. Thomas E. Snyder at Barro Colorado Island, Panama. The fourth progress report on this test was printed in detail in the 1933 Proceedings of the American Wood Preservers' Association. By permission of that association, your Committee gives the introduction to this report herewith as well as a number of the photographs showing the destruction of some of the principal specimens.

Introductory Paragraphs from:

AN INTERNATIONAL TERMITE EXPOSURE TEST—FOURTH PROGRESS REPORT[1]

By Geo. M. Hunt and T. E. Snyder

"The fourth report gives the latest inspection data on specimens of wood treated with various chemicals and exposed to the activities of termites in Australia, Barro Colorado Island (Canal Zone), Hawaii, and South Africa. Details of treatment, installation, and current inspections are given in the Proceedings of this Association for the past three years.

[1] From Proc. Am. Wood Preservers' Assn., 1933, p. 398.

"The test specimens were of sap pine about 2 by 4 by 18 inches in size. Four sets of such specimens were treated at the Forest Products Laboratory in 1928, one set for each of the four countries just named. Through the cooperation of Government officers in each country the specimens were installed in soil known to contain termites and inspections are made and reported at regular intervals. In 1931 a set of over 500 similar specimens was treated with a different series of chemicals and installed on Barro Colorado Island. Cost limitations made it impractical to send duplicates of this set to the other stations.

"Tables[2] show details as to the chemicals used, the absorptions, and the number of specimens at each exposure station and give the results of the inspections made at each station by the cooperating Government officers.

"These tables must not be considered as showing conclusively the relative effectiveness of the different preservatives. Comparison of the results from the different stations shows marked differences. For example, the nickel arsenate specimens are still sound at Barro Colorado Island, but in Australia all but one are either attacked or destroyed. On the other hand, the coal tar creosote specimens are sound in Australia and South Africa but are being attacked at Honolulu and Barro Colorado Island. These differences undoubtedly result from differences in climatic and exposure conditions and species of termites at the different stations, differences in amount or distribution of preservative in individual specimens, differences in the inspection methods and classification used by the several inspectors and perhaps other factors not yet recognized. The experiments should continue several years yet before conclusions are drawn. Use of these data for commercial promotion of any preservative is not warranted. . . . As the experiment grows older and a larger percentage of the more effective preservatives has failed it may be possible to show a definite relationship between the absorption and the life of the specimens in each preservative group. The depth and uniformity of penetration will, of course, have a very important influence for even with the best preservatives and good absorptions both termites and decay will sooner or later locate and destroy the places that have not been penetrated satisfactorily. Many of the specimens removed from test are being returned to Madison so that observations on penetration can be made when desired.

"The accompanying illustration shows the condition of some of the specimens removed from test at Barro Colorado Island at the time of the October 1932 inspection."

In addition to the stakes installed at Barro Colorado Island, the Bureau has a number of wooden framed wall-board buildings constructed of various woods both treated and untreated with the furnishing of treated furniture in a number of these buildings. No results have as yet been obtained from these test structures.

The Committee wishes again to emphasize that one of the most effective methods outside of the use of creosoted wood is to protect foundations, posts, pipes, etc., with metal shields. Fig. 1 shows a good type of shield around a concrete post. It would be better however to place this shield a foot or more higher than is indicated in the photo-

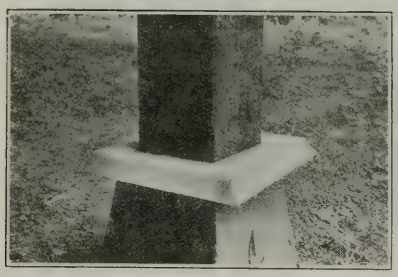
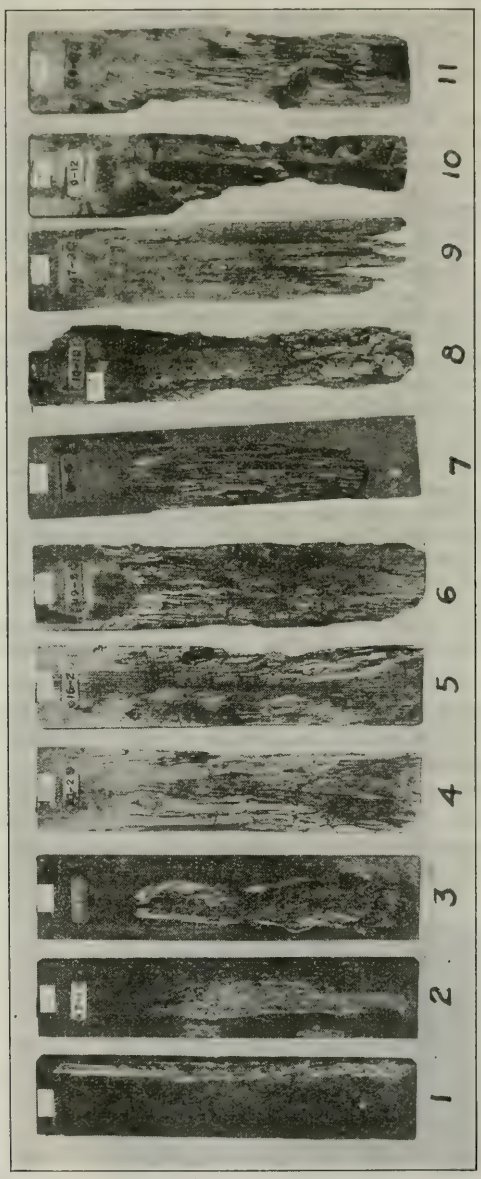


Fig. 1. Metal shield on concrete base, as a rule should be placed higher. (Photo sent by Dr. T. E. Snyder.)

[2] For these Tables consult the original article—See Note 1.



Typical specimens removed from test at Barro Colorado Island after 4⅓ years exposure. The preservatives used in the several specimens and their absorptions, in pounds per cubic foot, were as follows: (1) and (2) coal tar creosote 5.6 and 2.1, (3) halowax, 20.6, (4) and (5) zinc-meta-arsenite 0.58, (6) thallium sulphate 0.33, (7) sodium bicromate 0.68, (8) and (9) sodium fluosilicate 0.52 and 0.68, (10) Tanalith, 0.35, (11) arsenious acid, 0.71. Photo by James Zetek.

graph. Fig. 2 shows a number of buildings constructed by the Panama Administration. Particular attention is called to the spaces left between the top of the post and the concrete cap in which metal types of shields are to be inserted. This type of protection has now been made standard by the Government under Governor Burgess in the Canal Zone for all Government construction in that territory.

FIG. 2. Grooves ½-inch wide above concrete posts going all around; into these grooves when the building is finished the metal termite shield is fitted. Note that the walls do not reach the concrete sills but that they stop 6 inches below the grooves in the posts making it unnecessary to use the linear type of shield. Note also on one of the posts reinforcement rods stick out for the concrete steps, which will be below the grooves for the shields. (Photo sent by Dr. T. E. Snyder.)

Members of the Committee witnessed the actual treatment of a large number of untreated chestnut poles of the Long Island Lighting Co. in central Long Island by the Pfister Process. This is a process (patented) developed by Rudolph Pfister, a Swiss engineer, who has constructed and developed a portable device for puncturing poles below, at and above the ground line. Various types of preservatives are injected into the poles. It is impossible to give details reference this process at this time, because no actual results are yet available. The process will be watched with much interest in the hopes of reporting the details of chemical efficiency of the distribution of the preservative, processes, etc. in the report next year.

The California Termite Investigations Committee which has been at work for a number of years, has announced the forthcoming publication of a large volume (900 pages with 181 figures and illustrations) entitled "Termites and Termite Control". This volume is made up of 56 chapters divided into four parts:

Part I.—Termites and their Biology
Part II.—Chemical Investigations
Part III.—Termite Resistivity of Wood and Building Materials
Part IV.—Prevention and Repair of Termite Damage

This volume should be of very great interest to all engineers and judging from the table of contents, it will be a standard reference book on this important subject. This volume will be available January 1, 1934, for $5.00, which should be sent to the Sales Department, University of California, Berkeley, California. The Committee hopes at the time of the next annual convention to have a copy of this volume on hand for the personal inspection of those interested.

NOTES ON THE WHARF BORER

In its last year's report, the Committee reported the appearance in the United States of the wharf borer *(Nacerda Melanura,* Linn). This insect has continued its activity in and around New York Harbor. The Committee is indebted to Ralph H. Mann for some further notes on this insect. During the last year, Mr. Mann visited the plant of the General Aniline Corporation at Linden (Grasselli), N. J. He and the Committee are indebted to Wm. Miller, General Manager of the Corporation and to O. P. Aimone, the Plant Engineer, for the following data. The plant is located on 65 acres of land, 23 acres of which are covered with buildings of brick with timber frames and with some concrete floors on wood sub-floors. All structures are on untreated timber piling. Mr. Aimone estimated the number of piles at about 7500. After a discussion with the officers of this Company, Mr. Mann reports as follows:

"The plant is situated about ½ mile west of the Arthur kill, a New York harbor tidal estuary. The structures are built on the New Jersey tidal marshes on hydraulic sand filled ground. High tide levels plus 6.5 ft. mean sea level. Ground elevation about plus 9.0 ft. I estimate the pile cut-off elevations at elevations of from plus 1½ to 2.0 ft. above the ground line or elevation 10.5 to 11.0 above mean sea level. Their trouble (and it is a big one) is with wood borers in the constantly wet wood. The wetness being due to salt water. Mr. Miller said that he had sent specimens of the borer larvae to Dr. T. E. Snyder (Entomologist, Bur. of Entomology) U. S. Department of Agriculture, Washington, D. C. and to Thos. J. Headley, entomologist of Rutgers college. These authorities advised Mr. Miller that the specimens were "Nacerda Melanura Linn". From the description by Mr. Miller and the name I identified this as the "wharf borer", the source of the trouble suffered recently by the New York Dock Co. in the pile heads under their wharves on the Brooklyn side of the East River in New York Harbor. Later, when inspecting the piles with Mr. Aimone, I readily identified the worm as the larvae of the "wharf borer". The damage is tremendous here, that done to the New York Dock Co's. wharves cannot compare with it. The piles are riddled, many of them ruined and alive with the worms. Dr. Snyder's letter says that coal-tar creosote is the proper antidote. This company is heavily coating the piles least infected with creosote and are buying their first order of pressure creosoted timbers for replacements. One point of great interest as to the supposed hardiness of these wharf borers was noted by Mr. Aimone. In the timbers and piles under the house where tanks of $Na(OH)_2$—(sodium hydroxide) or caustic soda are stored, even though there is an ever present drip of this highly active chemical on the floor-beams and down to and over the piles, Mr. Aimone said that it was here that the borer attack was most severe. As to the drip danger, I was warned when in the building not to look up and so expose my eyes to possible drip of the caustic soda.

"I spoke to Mr. Miller this morning over the long distance telephone. I asked him the questions propounded by you in your letter:

"(a) The wharf borers were, Mr. Miller stated, the prime factors leading to the repairs now being made to the underpinning, (piles and low lying timbers) in the buildings of the General Aniline Corp. at Linden, N. J. At first before their definite knowledge of the wharf borer, the cause of the disintegration of the wood was always attributed to the oft-quoted "dry rot".

"(b) The infestation according to Mr. Miller today and also from my own observations made May 22, 1933, were in that portion of the pile within from the top two or three feet of the pile, or in that part of the pile that was continually dampened, not immersed, with which the salt water within the underlying soil was saturated."

"(c) The borers were discovered by chance. When the above noted caustic soda house developed leaking pipes, the flooring was torn up at the time that the repairs were

being made and the supporting piles disclosed. When these piles were cut into by the workmen and larvae were discovered in large numbers. This finding led Mr. Miller and Mr. Aimone to think that if such was the case under this building it might be the same for other foundations. The subsequent inspection of the piles under the other buildings proved the assumption to be correct. Mr. Miller said today that it was his opinion that when the piles were unearthed that spots of excessive 'decay' were disclosed. These spots when cut into with an axe or adze he said, would almost always bring to view many of the larvae. Mr. Miller advanced the opinion that he was probably fortunate in his discovery of the pests, because of the time in which his inspections were made. He said that the first knowledge he had of the borers, or their larvae was when they were in the 'worm' stage. He seems to feel that the borers may best be detected when they are in that stage of their life cycle. He first made the discovery of the larvae in March."

"(d) As to whether the borer attacks sound wood or wood in which decay has commenced, Mr. Miller is in doubt but he has heard of Dr. Snyder's statements concerning the Doctor's own doubts or lack of definite knowledge of this same point. Mr. Miller stated that he had a crew of men who were carefully painting creosote liberally on the heads of the uncovered piles that have been attacked as well as of those (few in number) which are as yet sound. This is in line with Dr. Snyder's recommendations. He says also that the darkness of the under floor seems to aid the propagation of the insects in the timber. However when I saw the plant last May, the piles that I was shown and from which I dug out many specimens of thriving borers was in piling in the outer tier of piles and on the southwest side of a building which I remember distinctly was very sunny.

"Mr. Miller thinks re' your advices to railroad port engineers, that the advice should be as to *when* to look as well as where. The *how* according to Mr. Miller is to look from 2 ft. above the line of permanent saturation upwards for 3 or 4 ft. Then if surface evidences of 'dry rot' are seen, the pile should be cut into with an axe, adze or hatchet and the wharf borers will be evident."

A second series of notes sent by Mr. Mann deals with the continued attack of these insects in some piles of the New York Dock Company, 334 Furman St., Brooklyn, New York. Through the courtesy of Mr. Driver, Chief Engineer of the New York Dock Company, we are able to give the following notes:

"This afternoon, I made an appointment with L. E. Driver Chief Engineer, New York Dock Company, 334 Furman Str., Brooklyn, N. Y. The results of this call, in answer to your stated inquiries are:

"(a) Here the prime factors leading to the repairs to the 250 odd pile heads recently renewed by the New York Dock Company were the presence of heavy decay in the upper 3 ft. of the pile head. In most instances, Mr. Driver said, the decay was the result of the infestation of the wharf borers. For, when the infested and decayed pile heads were cut into, the larvae of the borer was almost always in evidence then:

"(b) Here again the first finding of the pests by Mr. Driver was a matter of chance. It happened that during the usual pier maintenance of a certain pier early in 1931 that Mr. Downing, the Dock Superintendent, saw a section of pile which had been cut off in the plumb posting operations. He cut into the piece and saw a worm. He expressed surprise and asked the job foreman about the bug. The foreman, a Mr. Hendricksen, a Scandanavian, told Mr. Downing that he should have seen the numbers of them he found when making repairs to pier No. 24 in February of this year (1931). The discovery led to Mr. Downing reporting these findings at once to Mr. Driver who ordered an inspection of all the piles of all the piers of his properties.

"(c) Mr. Driver says that the wharf borer works principally in his piers, from the point of pile cut-off downward about 3 ft.

"(d) He states that it is not always necessary for outcroppings of decayed wood to be seen on the outside of the pile. His method of looking for the borers is to cut into any decayed spots seen on the body of the pile or to sound the pile with a light mall. If the pile sounds unsound or hollow, cuts are made with a hand cutting tool and in many instances, the borer larvae are found.

"(e) Mr. Driver reports that the presence of the larvae from his experience seems not to be in conformance with any cycle. He has found them (larvae) in Feb., March, April, May, June and July. There have been no reports as to these findings in the Winter months.

"Mr. Driver when renewing any borer infected timbers or pile heads, has adopted the policy of replacing with pressure creosoted material. He does not believe painting with creosote to be of any real use. If a pile head is found affected by these borers the policy is to permit the borer activities to progress until the pile has so deteriorated that it must be removed and replaced in the schedule of ordinary maintenance. He feels that the wharf borer only attacks wood in which ordinary decay has started, *but* after the borer has made his home in the pile or timber, the deterioration is very swift. Much more rapid is the destruction than in timbers where decay infection is the sole destructive agent."

From these two reports it appears that the insect is still active. We do not know, however, whether it will attack only wood that is starting to decay or has decayed or whether it will also go into sound wood (untreated) or sound creosoted wood.

Your Committee presents these notes to keep the Association advised and with the suggestion that when wharf structures undergo general repairs that signs of the presence of the borers be looked for. The Committee furthermore requests that anyone who does find evidence, communicate with the Committee so that we may keep the information as to its appearance and behavior up to date.

Conclusion

Your Committee recommends that this report be accepted as information.

Appendix F

(6) LOSS OF PRESERVATIVE IN TREATED TIES IN TRACK DUE TO USE OF OIL-BURNING WEED DESTROYERS

C. S. Burt, Chairman, Sub-Committee; G. B. Campbell, C. C. Cook, H. R. Duncan, W. R. Goodwin, L. B. Holt, R. S. Hubley, R. P. Hughes, A. J. Loom, L. J. Reiser, T. H. Strate.

Your Committee has continued its investigation and study with reference to the loss of preservative in treated ties due to repeated use of oil-burning weed destroying machines. Previous reports in connection with this study were published in the Proceedings for 1930, pages 751 to 757 inclusive, and in Volume 33, 1932 Proceedings, pages 547 to 549 inclusive. These reports give information in detail concerning experiments that the Committee has undertaken from time to time, however, a brief description of this is repeated here in that these same tests have been continued through the current weed burning season.

Pieces $2'' \times 8'' - 8'$ were cut from $6'' \times 8'' - 8'$ thoroughly air seasoned White Oak, Red Oak, Hard Maple, Beech, Sycamore and Southern Yellow Pine ties. One piece was cut from the face side of each tie and the heart center eliminated. These were treated with A.R.E.A. grade 1 distillate oil, 80–20 mixture of grade 1 creosote and coal-tar, and 45–55 mixture of grade 1 creosote and California crude-oil, by the Lowry and Reuping processes, with final retention of preservatives varying from 3 to 10 lbs. per cubic foot of wood. Retention of preservatives was determined by careful weighings of each piece before and after treatment. One piece from each tie was placed in track and subjected to operations of the wood burning machine, whereas the mate to each such piece was placed in adjoining track but not gone over by the weed burner. These pieces that were not subjected to operations of the machine served as a means to determine natural changes occurring during the course of the experiment, such as, change in moisture content and loss of oil by evaporation. All test pieces were carefully weighed before each operation, reweighed immediately afterward and calculations recorded.

The same test pieces have been used for these several different burnings, and charts have been prepared showing complete results of such tests in connection with individual

INDIVIDUAL

Piece Number										
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
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27										
28										
29										
30										
31										
32										
33										
34										
35										
36										
37										
38										
39										
40										
Pounds										
Av.Wt. Not Burne										
Av.Wt. Burned	42.10	40.90	0.00	40.17	[illegible]	40.09	40.90	44.13	[illegible]	[illegible]

Remarks: Two pieces cut from each of 20 square sawed Grade 3 ties seasoned 12 months. One piece sawed from each face. One piece from each tie placed in track subjected to operation of weed burner and its mate placed in track not affected by weed burner. Each piece is numbered for identification. Pieces are all taken from track and weighed at time of weed burning each year, to determine if there is any difference in loss of weight between pieces subjected to operation of weed burner and those not.

Individual weights on $1 pieces of Southern Pine laid in track to determine loss due to operation of Weed Burner - Size of Pine 8"x8"-8' - Treated with Straight Creosote Oil

Weight before Treated July 26-28-31, 1931		Weight after Treated July 29-30-31, 1931		Net Gain After Treatment		Weight Aug. 24, 1931 1st Burning Test				Weight Sept. 6, 1931 2nd Burning Test (1)					Weight Sept. 7, 1932 3rd Burning Test				Weight (3) Sept. 16, 1932 4th Burning Test				Weight July 26, 1933 5th Burning Test				Weight Aug. 5, 1933 6th Burning Test			
						Before		After		Before		(2) After			Before		After		Before		After		Before		After		Before		After	
Not Burned	To be Burned	Not Burned	To be Burned	Not Burned	To be Burned	Not Burned	To be Burned	Burned	Loss by 1st Burning	Not Burned	To be Burned	Burned	Loss by 2nd Burning		Not Burned	Burned	Burned	Loss by Burning	Not Burned	Burned	Burned	Loss by Burning	Not Burned	Burned	Burned	Loss by Burning	Not Burned	Burned	Burned	Loss by Burning
33.75	37.25	38.75	41.50	5.00	4.25	39.50	42.94	42.94	.00	44.00	48.00	47.50	.50		45.50	45.75	45.75	.00	*46.00	48.00	47.50	.50	39.50	43.75	43.75	.00	39.50	45.25	45.00	.25
34.00	29.25	37.75	31.50	1.75	2.25	37.65	32.53	32.41	.12	38.75	32.75	32.75	.00		36.00	31.25	31.75		*36.50	32.25	32.00	.25	36.25	31.50	31.50	.00	36.25	32.25	32.00	.25
30.75	36.75	36.75	37.00	6.00	6.25	38.94	38.31	38.28	.03	42.75	42.25	41.75	.50		43.50	40.75	40.00	.75	*45.75	41.50	41.50	.00	36.25	45.75	45.00	.75	45.25	45.00	.25
28.25	28.25	29.75	32.00	1.50	3.75	32.94	33.47	33.47	.00	35.75	35.75	35.25	.50		33.25	31.25	31.75		*34.25	33.75	33.25	.50	34.75	37.00	36.50	.50	34.00	36.00	35.75	.25
29.75	27.50	35.00	31.75	5.25	4.25	35.91	33.16	33.16	.00	39.25	35.80	35.00	.80		36.00	34.25	34.50		*36.00	35.75	35.25	.50	36.25	31.25	31.00	.25	37.75	33.75	33.75	.00
29.50	31.25	32.25	32.50	2.75	1.25	32.78	32.54	32.54	.00	35.75	32.75	32.50	.25		33.25	31.00	31.25		*35.25	31.75	31.50	.25	33.00	31.00	31.00	.00	32.25	31.50	31.25	
28.25	29.75	32.75	33.00	4.50	3.25	34.50	33.16	32.94	.22	38.50	35.50	35.00	.50		35.00	32.25	32.25	.00	*36.25	34.00	33.50	.50	31.00	30.25	30.00	.25	31.25	31.75	31.75	.00
32.25	31.50	33.75	33.25	1.50	1.75	33.91	33.94	33.90	.04	34.75	34.75	34.25	.50		32.25	36.00	36.25		32.75	36.00	35.75	.25	32.00	36.75	36.00	.75	32.00	35.00	34.75	.25
29.25	29.50	48.25	41.25	19.00	11.75	47.00	40.66	40.54	.00	49.50	42.00	41.75	.25		47.75	40.50	40.50	.00	47.75	40.75	40.50	.25	44.75	38.50	38.25	.25	41.00	38.75	38.75	.00
29.00	27.50	36.25	32.75	7.25	5.25	35.69	32.51	32.19	.12	36.50	32.75	32.50	.25		33.50	30.80	30.50	.00	34.25	31.00	30.75	.25	33.00	30.75	30.25	.50	33.25	31.25	31.00	.25
25.75	24.00	28.75	29.50	5.00	5.50	28.91	28.75	28.63	.12	30.00	30.25	30.00	.25		28.25	29.50	29.75		28.75	29.75	29.75	.00	27.50	29.75	29.25	.50	27.50	29.25	29.00	.25
32.50	36.25	35.75	39.25	3.25	3.00	35.28	37.78	37.72	.06	35.75	38.25	38.00	.25		36.00	37.00	37.25		35.75	37.50	37.25	.25	33.75	37.00	36.50	.50	33.25	36.50	36.50	.00
26.25	27.25	34.25	33.25	6.00	6.00	34.21	32.06	32.00	.06	35.50	33.25	32.75	.50		31.75	32.00	32.25		32.25	32.75	32.50	.25	31.50	40.00	40.25	.25	31.25	36.00	35.75	.25
28.50	25.75	31.00	28.75	2.50	3.00	30.88	28.88	28.88	.00	30.75	29.00	28.50	.50		31.75	28.25	28.25	.00	31.50	28.25	28.25	.00	29.00	29.25	29.00	.25	29.00	28.25	28.00	.25
28.50	30.00	35.25	36.50	6.75	6.50	35.44	36.31	36.31	.00	37.50	37.50	37.25	.25		34.75	38.25	35.25	.00	35.50	34.75	34.75	.00	34.50	34.75	34.75	.00	34.50	35.75	35.75	.00
31.50	32.75	36.50	37.00	5.00	4.25	36.41	36.66	36.63	.03	39.00	38.50	38.00	.50		39.50	36.00	35.50		37.25	35.25	35.25	.00	37.00	35.00	34.75	.25	37.00	36.25	36.25	.00
32.50	34.75	45.50	45.75	10.00	11.00	45.97	45.09	45.09	.00	51.25	50.75	50.25	.50		48.75	48.75	48.25		50.00	46.25	45.75	.50	41.50	49.50	49.25	.25	42.50	50.50	50.25	.25
32.75	31.50	36.75	35.00	6.00	3.50	37.72	35.00	34.94	.06	38.50	35.75	35.50	.25		37.25	34.25	34.50		38.00	35.25	34.75	.50	37.50	34.25	34.00	.25	37.25	34.50	34.50	.00
32.50	34.50	41.25	39.75	5.75	5.25	40.13	38.78	38.75	.03	40.50	39.00	38.75	.25		39.00	38.25	38.50		39.25	38.50	38.25	.25	38.75	37.75	37.50	.25	38.75	37.75	37.75	.25
31.50	29.50	38.50	36.50	7.00	7.00	38.61	36.53	36.34	.19	41.25	38.50	38.00	.50		36.25	37.00	35.50	1.50	37.75	37.00	36.50	.50	36.25	39.25	38.00	.25	37.50	38.50	38.25	.25
27.75	28.00	34.50	34.25	6.75	6.25	33.78	35.28	35.16	.12	35.50	37.25	36.75	.50		32.75	38.25	38.50		33.25	34.75	34.50	.25	31.75	33.25	33.25	.00	32.00	34.50	34.50	.00
642.75	634.75	761.25	744.00	118.50	107.25	768.84	743.54	741.89	1.17	808.75	780.00	772.00	8.00				739.00		781.00	755.25	751.75	6.50	734.75	756.25	750.75	5.50	738.00	758.75	755.75	3.00

Remarks ----------

(1) Increase in weight due to rain Sept. 3rd.
(2) Part of loss in weight probably due to evaporation of part of water absorbed from rain Sept. 3rd. Weighed 4 to 5 hrs. after 1st weighing before burning.
(3) Heavy rail between burning period Sept. 7, 1932 to Sept. 16, 1932.

*Note - Burner operated in error over these pieces

NOTE - Heavy rain between period July 26th to Aug. 5th.

INDIVIDUAL

Piece Number										
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36										
37										
38										
39										
40										
Pounds										
Av.Wt. Not Burned										
Av.Wt. Burned	42.10	48.90	6.80	46.75	2.15	46.65	48.50	44.75	[illegible]	[illegible]

Remarks: Two pieces cut from each of 20 square sawed Grade 3 ties seasoned 12 months. One piece sawed from each face. One piece from each tie placed in track subjected to operation of weed burner and its mate placed in track not affected by weed burner. Each piece is numbered for identification. Pieces are all taken from track and weighed at time of weed burning each year, to determine if there is any difference in loss of weight between pieces subjected to operation of weed burner and those not.

Individual weights of 51 pcs. of Oak laid on track to determine loss due to impregnation of Wood Burner - Size of Oak 2"x2"x4' - Treated with Creosote Oil

Weight Before Treatment (Aug. 24, 1921)	Weight after Treatment (Sept. 6, 1921)	Net Gain After Treatment	Weight Aug. 24, 1921 1st Burning Test After: Not Burned	To be Burned	Burned	Loss by 1st Burning	Weight Sept. 6, 1921 2nd Burning Test (1) Before: Not Burned	To be Burned	Burned	(2) After: Loss by 2nd Burning	Weight Sept. 7, 1932 3rd Burning Test Before: Not Burned	To be Burned	Burned	After: Loss by Burning	Weight (3) Sept. 16, 1932 4th Burning Test Before: Not Burned	To be Burned	Burned	After: Loss by Burning	Weight July 28, 1933 5th Burning Test Before: Not Burned	To be Burned	Burned	After: Loss by Burning	Weight Aug. 8, 1933 6th Burning Test Before: Not Burned	To be Burned	Burned	After: Loss by Burning
48.75	42.75	6.00	52.50	52.75	7.75	8.00	51.00	50.75	50.50	.25	46.00	46.25	46.00	.25	48.00	48.25	48.00	.25	47.25	47.00	46.75	.25	47.25	47.00	47.00	.00
54.25	51.75	2.50	57.25	57.75	3.75	6.75	54.75	55.00	54.81	.19	50.50	53.25	53.50		50.75	53.25	53.00	.25	50.25	51.75	51.25	.50	50.25	51.75	51.75	.00
49.00	47.75	1.25	56.25	55.00	6.75	5.25	53.75	53.00	52.70	.30	50.50	50.00	50.00	.00	50.75	50.00	49.50	.50	50.00	49.00	48.50	.50	49.50	49.75	49.75	.00
49.50	41.75	7.75	56.50	54.75	7.50	8.00	53.00	53.25	53.00	.25	49.50	51.50	51.75		50.00	51.50	51.25	.25	49.25	50.50	50.25	.25	49.00	50.50	50.25	.25
43.50	41.75	1.75	50.87	54.00	8.25	9.00	50.87	53.00	53.00	.00	47.75	52.25	52.25	.00	48.00	51.75	51.50	.25	47.00	50.75	50.25	.50	47.00	50.25	50.00	.25
49.50	41.75	7.75	56.75	54.75	6.25	8.00	54.14	52.50	52.25	.25	50.75	53.50	53.25	.25	51.00	52.75	52.50	.25	50.00	50.75	50.50	.25	50.00	50.50	50.25	.25
42.25	41.75	.50	54.50	56.00	9.25	10.00	52.00	55.25	55.00	.25	51.00	56.00	56.00	.00	51.00	55.75	55.25	.25	50.00	52.75	52.50	.25	50.75	52.75	52.75	.00
55.50	49.00	6.50	60.00	56.75	7.50	7.75	57.25	55.00	54.75	.25	52.75	52.25	51.50	.75	53.25	51.50	51.25	.25	52.50	49.75	49.50	.25	52.00	49.75	49.50	.25
47.25	50.00	2.75	54.00	55.00	6.75	6.00	52.00	54.75	54.75	.00	50.00	52.25	52.25		50.00	50.25	51.00	.25	48.75	51.25	51.00	.25	48.75	51.25	51.00	.25
49.25	52.25	3.00	58.25	52.50	3.50	5.50	50.34	50.75	48.75	.25	47.50	47.25	47.50		47.75	47.50	47.25	.25	47.00	45.75	45.50	.25	47.00	46.00	46.00	.00
49.25	45.25	4.00	53.50	52.50	4.25	4.25	50.25	51.25	51.00	.25	49.00	49.00	49.25		49.00	49.25	48.75	.50	48.50	49.00	48.75	.25	48.50	48.75	48.75	.00
48.75	44.75	4.00	47.50	51.00	4.75	5.25	46.09	46.75	46.75	.00	44.50	47.00	47.25		44.00	47.00	46.25	.25	44.25	46.00	46.25	.25	44.25	46.25	46.25	.00
54.25	51.25	3.00	58.75	54.25	3.50	3.00	51.46	52.50	52.50	.00	50.50	51.50	51.75		50.75	51.75	51.50	.25	50.75	50.75	50.50	.25	50.75	50.50	50.25	.25
49.75	49.00	3.25	52.75	51.75	3.00	3.25	49.69	50.25	50.00	.25	47.50	50.00	49.75	.25	47.50	50.00	49.75	.25	47.25	47.00	47.00	.00	47.00	47.00	47.00	.00
52.50	50.75	1.75	55.25	54.50	2.75	3.75	52.66	53.50	53.25	.25	50.75	50.00	50.00	.00	50.75	50.00	50.00	.00	50.00	50.25	50.25	.00	50.25	50.25	50.00	.25
51.75	49.50	2.25	55.25	53.50	3.50	4.25	52.47	52.75	52.75	.00	50.25	49.25	49.25	.00	50.25	49.25	49.25	.00	50.50	49.25	49.00	.25	49.50	49.50	49.50	.00
48.25	43.50	4.75	49.00	51.75	6.75	8.25	47.24	52.00	52.00	.00	46.25	48.25	48.50		46.25	48.50	48.25	.25	46.00	48.50	48.25	.25	46.00	48.50	48.50	.00
55.75	52.00	3.75	58.75	59.75	7.00	6.75	55.44	56.00	55.75	.00	53.50	53.75	53.75	.00	53.50	53.75	53.75	.00	53.00	52.50	52.25	.25	52.50	52.75	52.75	.25
55.25	50.75	4.50	59.50	58.25	7.50	7.50	57.22	58.00	57.50	.25	56.00	57.50	57.00	.00	54.75	57.25	57.00	.25	54.75	56.25	56.00	.25	55.00	55.00	55.00	.00
49.25	44.50	4.75	54.00	52.50	4.75	5.75	50.66	53.25	49.25	.00	51.75	51.75	47.25	.25	50.50	46.50	46.25	.25	50.25	46.50	46.25	.25	46.50	46.50	46.25	.25
46.25	44.00	2.25	52.50	52.75	6.25	6.75	50.75	51.25	51.75	.00	48.25	49.50	49.50	.00	48.25	49.50	49.50	.00	48.00	49.00	48.75	.25	48.00	49.00	49.00	.00
2012.75	999.75	1142.25	1135.75	1126.75	126.75	135.50	1092.93	1091.45	1089.44	2.01	1111.00	1109.25	1106.50	2.75	1049.75	1068.25	1063.75	4.50	1036.50	1043.50	1038.00	5.50	1035.50	1043.00	1041.00	2.00

Remarks ---------

(1) Increase in weight due to rain Sept. 3rd.
(2) Part of loss in weight probably due to evaporation of part of water absorbed from rain Sept. 3rd. Weighed 4 to 6 hrs. after 1st weighing before burning.
(3) Heavy rain between burning periods Sept.7, 1932 to Sept.16, 1932

NOTE - Heavy rain between period July 26th to Aug. 5th, 1933.

INDIVIDUAL

Piece Number																		
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Pounds	842	849	978	1003	136	154	935	960½	43	42½	933	953½	932	894½	915½	891	87	87½
Av.Wt. Not Burned		42.45		50.15		7.70		48.02		2.13		47.67			45.77			4.38
Av.Wt. Burned	42.10		48.90		6.80		46.75		2.15		46.65		46.50	44.73		44.55	4.35	

Remarks: Two pieces cut from each of 20 square sawed Grade 3 ties seasoned 12 months. One piece sawed from each face. One piece from each tie placed in track subjected to operation of weed burner and its mate placed in track not affected by weed burner. Each piece is numbered for identification. Pieces are all taken from track and weighed at time of weed burning each year, to determine if there is any difference in loss of weight between pieces subjected to operation of weed burner and those not.

Individual weights of 50 pieces of ties used in Test to determine loss of preservative due to operation of weed burning machine. Each piece 2" x8" x8', treated with 80-20 mixture Creosote coal-tar solution, and straight Distillate creosote oil.

Kind of Oil	Kind of Wood	Weight before Treatment July 26, 1930. Not Burned	Weight before Treatment July 26, 1930. To be Burned	Weight after Treatment July 27, 1930. Not Burned	Weight after Treatment July 27, 1930. To be Burned	Net Gain After Treatment Not Burned	Net Gain After Treatment To be Burned	Weights before and after 1st. Burning- Sept. 2, 1930. Before Not Burned	Before To be Burned	After Not Burned	After Burned	Loss Not Burned	Loss Burned	Weights before and after 2nd. Burning- July 27, 1931. Before Not Burned	Before To be Burned	After Not Burned	After Burned	Loss Not Burned	Loss Burned	Weights before and after 3rd. Burning- Sept. 2, 1931. Before Not Burned	Before To be Burned	After Not Burned	After Burned	Loss Not Burned	Loss Burned	Weights before and after 4th. Burning- Oct. 14, 1933. Before Not Burned	Before To be Burned	After Not Burned	After Burned	Loss Not Burned	Loss Burned	Loss to Date Not Burned	Loss to Date Burned
80-20 Creo.Tar	Pine		52.50		57.50		5.00		57.00		57.00		0		57.00		56.00		1.00		55.00		55.00		0		52.00		52.00		0		1.00
" "	"		39.50		43.00		3.50		42.50		42.50		0		43.00		41.00		2.00		40.50		40.00		.50		39.00		39.00		0		2.50
Dst. Creosote	"		43.50		51.50		8.00		52.00		51.50		.50		57.00		55.00		2.00		52.50		52.00		.50		49.50		49.50		0		3.00
" "	"		52.50		60.00		7.50		61.00		61.00		0		65.50		63.00		2.50		61.50		60.50		1.00		54.50		54.50		0		3.50
" "	"		42.50		50.00		7.50		47.00		47.00		0		47.50		46.50		1.00		46.00		46.00		0		45.50		45.50		0		1.00
80-20 Creo.Tar	"	53.00		59.00		6.00		60.00		60.00		0		63.00		60.50		2.50		58.50		58.00		.50		54.00		54.00		0		3.00	
" "	"	46.00		51.00		5.00		49.50		49.50		0		50.50		48.50		2.00		48.00		48.00		0		46.00		46.00		0		2.00	
Dst. Creosote	"	48.00		57.50		9.50		56.00		56.00		0		58.00		57.00		1.00		55.50		54.50		1.00		50.00		50.00		0		2.00	
" "	"	39.50		45.50		6.00		43.50		43.25		.25		45.00		43.00		2.00		42.50		42.50		0		40.00		40.00		0		2.25	
" "	"	50.00		58.00		8.00		56.00		55.50		.50		59.00		57.50		1.50		56.00		55.50		.50		53.00		53.00		0		2.50	
80-20 Creo.Tar	"		44.00		52.00		8.00		54.50		53.50		1.00		58.50		57.00		1.50		55.50		55.00		.50		48.50		48.50		0		3.00
Dst. Creosote	"		43.50		51.50		8.00		49.50		49.00		.50		50.00		48.50		1.50		48.00		47.50		.50		44.50		44.50		0		2.50
80-20 Creo.Tar	"		52.00		56.00		4.00		53.00		53.00		0		58.00		57.00		1.00		54.50		53.50		1.00		50.00		49.50		.50		2.50
" "	"		41.00		45.00		4.00		45.00		45.00		0		45.00		43.50		1.50		43.00		42.00		1.00		41.00		41.00		0		2.50
Dst. Creosote	"		47.50		57.50		10.00		56.00		56.00		0		61.50		60.50		1.00		57.50		57.50		0		49.50		49.50		0		1.00
80-20 Creo.Tar	"	44.00		53.00		9.00		55.00		55.00		0		60.50		58.50		2.00		56.50		55.50		1.00		48.50		48.50		0		3.00	
Dst. Creosote	"	41.00		48.00		7.00		45.50		45.50		0		44.50		45.00		1.50		44.00		43.50		.50		41.00		41.00		0		2.00	
80-20 Creo.Tar	"	41.00		47.50		6.50		47.50		46.50		1.00		49.00		47.00		2.00		45.50		45.00		.50		42.50		42.00		.50		4.00	
" "	"	39.00		42.50		3.50		41.50		41.00		.50		42.50		40.50		2.00		39.50		39.50		0		39.00		39.00		0		2.50	
Dst. Creosote	"	49.50		60.00		10.50		58.50		58.50		0		62.50		61.00		1.50		59.00		58.00		1.00		53.00		53.00		0		2.50	
80-20 Creo.Tar	White Oak		97.50		101.50		4.00		94.50		94.50		0		88.00		86.00		2.00		85.00		85.00		0		81.00		81.00		0		2.00
" "	"		87.00		92.00		5.00		85.00		85.00		0		79.00		78.00		1.00		77.50		77.50		0		75.00		74.50		.50		1.50
" "	"		81.50		89.50		8.00		84.00		84.00		0		80.00		79.00		1.00		78.00		78.00		0		74.50		74.00		.50		1.50
" "	"		90.50		94.00		3.50		86.00		86.00		0		80.00		78.00		2.00		77.50		77.00		.50		76.00		75.50		.50		3.00
Dst. Creosote	"		77.00		82.00		5.00		78.50		78.00		.50		73.00		71.50		1.50		72.00		71.00		1.00		68.50		68.50		0		3.00
80-20 Creo.Tar	"	77.50		81.50		4.00		75.00		76.00		1.00		71.00		69.50		1.50		69.50		69.50		0		66.00		66.00		0		2.50	
" "	"	87.00		92.00		5.00		86.00		86.00		0		80.50		78.50		2.00		79.00		78.00		1.00		75.50		75.50		0		3.00	
" "	"	77.00		84.00		7.00		78.00		77.50		.50		75.00		72.50		2.50		72.50		71.50		1.00		67.50		67.50		0		4.00	
" "	"	84.00		89.00		5.00		81.50		81.50		0		75.50		73.00		2.50		73.50		73.50		0		71.00		71.00		0		2.50	
Dst. Creosote	"	69.50		75.00		5.50		71.50		71.00		0		68.00		65.50		2.50		65.50		65.50		0		63.00		63.00		0		2.50	
80-20 Creo.Tar	Red Oak		67.00		74.00		7.00		59.50		59.50		0		63.00		62.00		1.00		61.50		61.00		.50		60.00		60.00		0		1.50
" "	"		92.00		99.00		7.00		91.00		91.00		0		87.00		85.50		1.50		84.00		84.00		0		80.00		80.00		0		1.50
" "	"		78.00		84.50		6.50		78.50		78.00		.50		71.50		70.00		1.50		70.00		70.00		0		68.50		68.50		0		2.00
Dst. Creosote	"		82.00		90.50		8.50		86.50		85.50		0		79.50		78.00		1.50		77.00		76.50		.50		73.50		73.00		.50		2.50
" "	"		83.00		90.50		7.50		85.00		85.00		0		78.50		77.50		1.00		76.50		76.50		0		73.00		73.00		0		1.00
80-20 Creo.Tar	"	64.50		71.00		6.50		66.00		66.00		0		61.00		58.50		2.50		58.00		58.00		0		55.00		55.00		0		2.50	
" "	"	78.00		84.50		6.50		79.00		79.00		0		74.50		73.00		1.50		72.00		72.00		0		69.00		69.00		0		1.50	
" "	"	70.00		73.00		3.00		66.50		66.50		0		61.50		60.50		1.00		59.00		59.00		0		57.50		57.50		0		1.00	
Dst. Creosote	"	83.00		91.00		8.00		83.50		83.50		0		76.50		75.50		1.00		74.00		73.50		.50		70.50		70.50		0		1.50	
" "	"	75.50		83.00		7.50		78.00		78.00		0		72.50		71.00		1.50		70.50		70.50		0		65.50		65.50		0		1.50	
80-20 Creo.Tar	Hardwood		64.50		72.00		7.50		67.00		67.00		0		64.00		62.00		2.00		62.50		62.50		0		61.50		61.00		.50		2.50
" "	"		58.00		67.00		9.00		61.50		61.50		0		60.00		59.00		1.00		58.00		58.00		0		57.00		57.00		0		1.00
" "	"		57.00		67.50		10.50		64.00		63.50		.50		60.50		59.00		1.50		59.00		59.00		0		57.50		57.50		0		2.00
" "	"		52.50		59.00		7.50		56.00		56.00		0		53.50		52.00		1.50		51.50		51.50		0		51.00		51.00		0		1.50
" "	"		59.00		70.00		11.00		65.50		65.50		0		64.00		62.50		1.50		62.00		62.00		0		61.00		61.00		0		1.50
" "	"		55.50		66.50		11.00		61.00		61.00		0		59.50		58.00		1.50		57.50		57.50		0	56.50		56.50		0		0	1.50
" "	"		56.00		65.50		9.50		61.00		61.00		0		59.00		58.50		.50		58.00		58.00		0	56.00		56.00		0		0	.50
" "	"		59.00		69.50		10.50		64.00		64.00		0		62.50		62.00		.50		60.50		60.50		0	58.50		58.50		0		0	.50
" "	"		49.50		60.00		10.50		55.00		55.00		0		55.00		53.00		2.00		53.00		53.00		0	51.50		51.50		0		0	2.00
Dst. Creosote	"		56.50		71.50		6.00		67.00		67.00		0		65.50		64.50		1.00		63.50		63.50		0	62.00		62.00		0		0	1.00
		1,217.00		1,346.00		129.00		1277.50		1273.75		3.75		1252.50		1216.00		36.50*		1198.50		1191.00		7.50	7.50	1413.00		1420.50		.50	3.00	48.25	
			1,870.50		2,090.00		220.50		1974.00		1972.00		3.50		1926.00		1884.00		42.00*		1856.50		1861.00				1490.00		1487.00				54.00

*Heavy loss in weight due to hard rains between weighings.

... Central R.R. Co.
..., Miss.
..., 1933.

Analysis of Preservatives used in above tests.

A.R.E.A. Grade 1 Distillate Oil		80-20 Mixture Grade 1 - Creosote Oil and Coal Tar	
Up to 210°C	2.80%	Up to 210°C	3.60%
" " 235°	14.30	" " 235°	7.20
" " 315°	35.20	" " 315°	33.40
" " 355°	20.00	" " 355°	17.70
Residue (Soft)	27.50	Residue (Soft)	38.00
Spec. Gravity	1.048 @ 38°	Spec. Gravity	1.093 @ 38°
Water - Trace		Water - Trace	

INDIVIDUAL WEIGHTS OF 40 PIECES OF HARD MAPLE USED IN TEST TO DETERMINE LOSS OF PRESERVATIVE DUE TO OPERATION OF WEED BURNER
Each Piece 2″ × 8″ × 8′, Treated with Mixture of 45 Per Cent No. 1 Creosote and 55 Per Cent California Petroleum

Piece Number	Before Treatment: April 28, 1931		After Treatment: April 29, 1931		Absorption		After Burning: Aug. 17, 1931		Loss to Date		Before Burning: Aug. 8, 1932		After Burning: Aug. 8, 1932		Before Burning: July 20, 1933		After Burning: July 20, 1933		Loss to Date	
	Burned	Not Burned	Burned	Not Burned	Burned	Not Burned	Burned	Not Burned	Burned	Not Burned	Burned	Not Burned	Burned		Burned	Not Burned	Burned		Burned	Not Burned
1		44		53		9		51½		1½		51½				49½		46		3½
2	44		50		6		48		2		48		48	46½			4			
3		41		51		10		49		2		50				47½		46½		3½
4	40		50		10		48		2		48		48	46½			3½			
5		42		51		9		49		2		49				46		42½		5
6	41		46		5		44½		1½		44½		44½	43			3½			
7		43		48		5		46		2		45				43		44		5
8	43		47		4		45		2		45		45	44			3			
9		45		53		8		51		2		51½				48½		47		4½
10	43		51		8		49½		1½		49		49	47½			4			
11		40		49		9		47		2		47				46		47½		3
12	42		52		10		49½		2½		49		49	47½			4½			
13		43		53		10		50		3		50				48		46½		5
14	44		51		7		48½		2½		48		48	46½			4½			
15		44		49		5		46½		2½		46½				45½		43½		3½
16	44		48		4		47		1		47		46	44			4½			
17		44		50		6		48		2		48				46		46		4
18	41		50		9		48		2		48		48	46			4			
19		46		50		4		47½		2½		46				44½		45		5½
20	45		49		4		47½		1½		47½		47½	45			4			
21		45		53		8		50½		2½		49				47½		45		5½
22	45		51		6		47½		3½		47		47	45			6			
23		42		48		6		46		2		46				44		42		4
24	42		46		4		43½		2½		43½		43½	42			4			
25		41		51		10		49		2		49				46½		44		4½
26	39		48		9		46½		1½		46½		46½	44			4			
27		45		54		9		52		2		51				49½		48½		4½
28	45		53		8		50		3		50		50	48½			4½			
29		41		46		5		44		2		44				41½		40½		4½
30	40		45		5		42½		2½		42½		42½	41			4½			
31		42		48		6		45½		2½		45				43		42		5
32	42		48		6		45½		2½		45½		45½	42½			6			
33		40		46		6		43½		2½		43				41½		40		4½
34	39		44		5		42		2		42		42	40½			4			
35		39		51		12		48½		2½		48				46		41½		5
36	40		46		6		44		2		44		44	41½			4½			
37		42		48		6		46		2		46				45		45½		3
38	43		50		7		47½		2½		47½		47½	45½			4½			
39		40		51		11		50		1		48				46½		47½		4½
40	40		53		13		50½		2½		50½		50½	47½			5½			
Pounds	842	849	978	1003	136	154	935	960½	43	42½	933	953½	932	894½	915½		891		87	87½
Av. Wt. Not Burned		42.45		50.15		7.70		48.02		2.13		47.67			45.77					4.38
Av. Wt. Burned	42.10		48.90		6.80		46.75		2.15		46.65		46.50	44.73			44.55		4.35	

Remarks: Two pieces cut from each of 20 square sawed Grade 3 ties seasoned 12 months. One piece sawed from each face. One piece from each tie placed in track subjected to operation of weed burner and its mate placed in track not affected by weed burner. Each piece is numbered for identification. Pieces are all taken from track and weighed at time of weed burning each year, to determine if there is any difference in loss of weight between pieces subjected to operation of weed burner and those not.

test pieces. (See Exhibits A, B & C). In studying these charts it should be remembered that the figures have to do with test pieces only ⅓ the size of Grade 3 ties, and in making final analysis of the situation, these calculations should be applied to the cubical contents of regular 6 × 8 — 8′ ties in each case.

In addition to the tests described in Exhibits A, B & C, similar experiments on a somewhat smaller scale were conducted last year on the Rock Island. While figures regarding these tests are not available at this time, the results of burnings and subsequent weighings show practically no loss of preservative.

It has been suggested there might be a more damaging effect on the section of the tie outside rail, as, heat from the burners seems more intense at these points than it is in the center of the track. To develop information on this question the Rock Island placed two creosoted gum ties (full size ties, 6 × 8 — 8′) in track, parallel to the rail at ends of the track ties, and subjected these to operations of the weed burning machine. The results of this test are given below.

	Weight before Burning	*Weight after Burning*	*Loss in Weight*
Hewn 6 × 8 — 8′ Gum	143.75 lbs.	145.65	.10 lbs.
Sawn " "	120.25 "	120.00	.25 "

Because of the low heat conductivity of wood and the extreme short time of application of the heat, it is the opinion of the Committee that flames from the machine affect only the area of the cross tie near the surface of the face side. Following this thought extractions of creosote were made from two matched test pieces—from one which had been subjected to the weed burning machine 8 different times, and from the other half of the same set which was not burned. Analyses of the oil obtained from these pieces, together with that of the original oil used in treatment are shown below.

Imported distillate original oil		*From burned section of test piece*		*From section not burned*	
Up to 210°C	2.80	Up to 210°C	1.90	Up to 210°C	4.10
210° " 235°	14.30	210° " 235°	1.20	210° " 235°	1.00
235° " 315°	35.20	235° " 315°	5.85	235° " 315°	6.70
315° " 355°	20.00	315° " 355°	33.45	315° " 355°	30.50
Residue (Soft)	27.50	Residue (Soft)	55.20	Residue (Soft)	54.80
	99.80		97.60		97.10
Loss	.20	Loss	2.40	Loss	2.90
	100.00		100.00		100.00
Water—1%		Water—Trace		Water—Trace	
Specific Gravity	1.065 @ 38°C.	Specific Gravity	1.1036 @ 38°C.	Specific Gravity	1.1052 @ 38°C.

From the above it is noted that there is very little difference in the character of the oil remaining in these particular pieces of the two groups, at this time.

Results of the additional experiments would seem to bear out the opinion of the Committee as expressed in previous reports to the effect that the loss of preservative from treated ties by weight may be considered almost neglible. Attention is also directed to the figures which show an almost equal decrease in weight for pieces which were not subjected to the weed burning machine as compared to those that were burned.

Continued study fails to develop further facts of particular interest and importance relative to the effect of these machines on treated ties in track, but the Committee wishes to again call attention to several observations in this connection, which are given in previous reports on this subject, but which we think are of sufficient importance to be repeated at this time.

It is noted that the effect of weed destroying machines on treated ties, as regards the loss of preservative, diminishes almost directly in proportion to the increase in age of the tie in track. This is particularly applicable to ties of the hardwood group. Ties that have been in service more than three years are rarely affected unless they are mechanically worn or damaged by derailment. Old ties that are so damaged and worn are more often affected by the second burning because the flame is also communicated to the tie from dead burning grass and vegetation. Speed at which machines are operated is governed by the kind and growth of vegetation but at average operating speed the ties are subjected to the heat not more than 1½ seconds. It is of particular importance that machines be operated at the specified speed. Often, the rate of travel is lower than the speed required to meet conditions and the possibility of damage to the ties in track is thereby increased. This occurs most frequently when burning in yards or on sidings where the vegetation is sometimes much heavier than in main line track.

Untreated ties ignite much more readily than creosoted ties and burn freely, particularly so if they show any splintering from any cause, or if decay has developed. Burning of such ties may be considered beneficial rather than detrimental as the surface chars and destroys incipient fungus growth. As a good many ties do ignite either from the machine or from burning grass and vegetation, it is of utmost importance that section gangs closely follow the machine to extinguish such fires as quickly as possible. Machines should not be allowed to stand in one place immediately after the flame has been shut off as the heat radiating from the apron will damage the ties beneath.

In many cases there seems to be more free oil on the outside of the ties after the weed burner has passed than before, and this adds a protective coating to the tie which probably retards volatilization of the lighter fractions of the preservative and to some extent should prevent checking. The kind of ballast and track dressing has much to do with the effect of these machines on ties, and needless to say the effect is lessened according to the protection provided by the ballast. Much of the failure of treated ties today may be attributed to mechanical wear, and such failure occurs directly under the rail which section is subjected to less heat than any other part of the tie because of the protection provided by the rail base and tie plate.

As already suggested, all experiments thus far along this line seem to indicate that little actual loss of preservatives may be expected from normal operation of weed burning machines. While on the other hand considerable damage to treated ties will follow careless operation of such machines. It is, therefore, strongly urged that every care be exercised to prevent abuse to ties in track because of careless operation of these machines, and that this work be most closely supervised by all concerned.

Action Recommended

It is recommended that this report be accepted as information and the subject discontinued.

APPENDIX G

(7) METHODS OF PROTECTION OF TREATED MATERIALS IN THE FIELD

L. J. Reiser, Chairman, Sub-Committee; C. C. Cook, R. S. Belcher, G. B. Campbell, H. R. Condon, G. M. Cornell, E. A. Craft, W. R. Goodwin, C. W. Greene, R. S. Hubley, R. P. Hughes, G. P. MacLaren, T. H. Strate, W. A. Summerhays, C. M. Taylor.

General Statement

TIES

In treatment of ties and timber to prevent decay, the life service to be obtained from proper treatment is largely dependent on adherence to definite rules in handling, care, and efficient use. Necessary precautions should, therefore, be observed to obtain maximum life service.

1. Care must be exercised when unloading creosoted ties to avoid fracture and exposing untreated wood. They should not be thrown down high embankments or on rails, rocks, or other materials where they may be splintered or fractured. They should not be removed from cars with sharp pointed or edged tools.

2. "Creosoted ties should be stacked as completely as practicable" (Manual, page 131, Fig. 5 and 6, Committee III) to retard evaporation of the preservative and prevent checking or warpage.

"They should be covered with cinders or dirt wherever exposed to falling sparks." (Manual, page 131, Committee III).

"Ties treated with zinc chloride or other water borne salts should be open stacked as shown in Fig. 1 to 4 inclusive, page 131, Manual, Committee III," and allowed to season as specified.

"Zinc treated ties should be stacked so as to obtain free circulation of air with minimum contact." (Addition to Manual, Bulletin 337, Committee III).

"Ties should be allowed to season and dry for at least 60 days after treating at either treating plant or on the line before being placed in track." (Addition to Manual, page 10, Bulletin 337, Committee III).

"Stored ties of any kind should not be accumulated in groups of stacks without adequate spacing between groups to permit fire control nor without maintenance of bared or plowed ground at least three feet wide around the storage yard wherever fire from adjacent areas may spread." (Manual, page 130, Committee III).

3. Adzed and bored ties must be used with weight of rail for which prepared and spikes must be driven in bored holes regardless of line end. Boring of ties results in increased penetration of preservative surrounding spike area and careless spiking of bored ties should not be permitted.

4. "Ties must be moved with tongs so as to reduce damage incident to handling. Picks, mauls, sledges, and spiking hammers, must not be used in moving ties or placing them in position beneath the rail." (Manual, page 828, Committee XII).

"If ties are driven at all, this should be done with wooden maul. (Manual, page 1277, Committee XVII).

5. Ties split or cracked where bored will cause spike holding power to be greatly impaired. Plugs should not be driven in such defects and spiking continued which will result in further injury to tie. It is, therefore, desirable to vary from standard practice in positioning of spike by reversing position where possible to avoid spiking in crack. Use of plates with four spike slots will facilitate use of most desirable location with ties having such defects.

6. "Where choice has to be made between distributed ties of unequal age, but equal suitability for given trackage, the oldest ties should be used first, providing it is not practicable to determine and use the least durable tie first and to see that no tie is held in storage longer than one-fifth of its estimated life in track." (Manual, page 132, Committee III).

7. "Preserved ties may be destroyed by mechanical action long before it is decayed, and, therefore, should be protected by economical devices when the mechanical life limits the life of the tie." (Manual, page 1273, Committee XVII).

8. "When applying tie plates care should be exercised to see that the plates have a full, even bearing on the ties, that the track is in correct gauge before they are spiked to the tie, and that the shoulder of the plate rests against the base of the rail for the full width of the plate." (Manual, page 831, Committee XII).

9. "Spikes should be started vertically and square and so driven that the face of the spike shall come in contact with the base of rail. The spike should never have to be straightened while being driven," (Manual, page 231, Committee V) "but not driven so far as to cause the neck to bend and/or the head to crack or break off." (Manual, page 831, Committee XII).

Careless driving will result in mutilating fiber around spike hole, contributing to loose spikes with accumulative moisture and infection in untreated wood at center of tie.

10. At locations where it is frequently necessary to clean ashpans, ties should be provided with covers of sheet metal. This covering should rest on furring, providing clearance of not less than one-inch to prevent charring of ties.

11. When making inspection of treated ties in track for renewals, they should not be tested or marked with pick or adze, or other sharp tools which may cut or puncture through to the untreated wood and cause infection and decay in the untreated interior of the tie.

12. Ties which are much checked or split should not be used at joints, as spikes frequently work out from such at this location and require respiking. Excessive spiking shortens life of the tie and care should be exercised that joint ties be of such quality as to insure maximum strength and service.

13. Loose spikes indicate abnormal wear on walls of spike holes, contributing to easy access of water, thereby subjecting such area to decay. All such spikes should be withdrawn and creosoted "tie plugs should be driven to full depth and with the widened head parallel with the tie so as to take up any enlarging of the hole back of the spikes." (Manual, page 132, Committee III).

"Whenever spikes are drawn from ties, creosoted tie plugs must be driven into all holes except in ties which are to be renewed that season. In replacing spikes they must be driven in to the plugs." (Manual, page 828, Committee XII).

Treated tie plugs of standard dimensions should always be available as required to plug holes when respiking as specified, pages 132 and 133 in Manual.

14. Treated ties bruised by derailments but still serviceable at location where damaged may be adzed to remove crushed fibers, such adzed surfaces to be protected by application of hot creosote oil. Ties damaged by derailment or on account of mechanical wear to such extent as to be unserviceable at that location should be salvaged for use in less important trackage or for other uses such as fencing, bulkheading, etc., according to their value.

15. "The Supervisor must frequently inspect ties removed from track to see if any have been removed which might have remained in the track with safety until the next inspection. This report shall be carefully checked by the Division Engineer and where any unusual or unfavorable condition is indicated, a thorough investigation shall be made to insure proper renewals." (Manual, page 827, Committee XII).

16. In relaying of rail and tie plates where adzing of ties is necessary due to wear, ties should be adzed to depth of rail cut or wear in straight line across face parallel with rail, the length adzed to be governed by size of tie plate used. Before adzing all spike holes should be full driven with creosoted plugs and newly adzed surfaces well cleaned and given a thorough application of hot creosote.

17. In disposing of worthless ties by burning, they should be burned at a distance not less than fifteen feet from the nearest end of ties in track, and in case they cannot be piled twenty-five feet therefrom, piles for burning should not consist of mor than forty ties. They should not be burned near bridges, telegraph poles, newly creosoted ties, or other treated or combustible materials. Where there is any possibility of fire spreading to adjoining property, it must be carefully watched and kept under control.

18. "For best results it is recommended that certain sections of track be selected on each railroad for the purpose of making accurate tests covering the life of treated and untreated ties of various kinds of timber and various treatments, and that a record be kept of all ties in these sections of track in order to be able thereafter to improve treatment. All ties inserted in such test sections should be marked with dating nails, and, if necessary, with other identification marks." (Manual, page 1273, Committee XVII).

BRIDGE TIMBER

1. Timber is creosoted to protect it from attacks of fungi which causes decay, and any cutting that exposes the untreated interior is injurious to life of timber and renders it very little better than untreated material.

2. "When ordering treated timber state exact sizes and lengths desired. Cutting treated timber to length in the field shortens its life and should be done only when unavoidable." (Addition to Manual, page 1202, Bulletin 337, Committee XII).

3. "When cutting to length is unavoidable or when necessary to adze or otherwise disturb the surface of treated timber, such surfaces must be swabbed with a liberal quantity of hot preservative followed by two applications of hot sealing compound." (Addition to Manual, Rule 1204, Bulletin 337, Committee XII).

4. "When necessary to bore treated timber in the field, all holes must be treated with hot preservative, followed by sealing compound applied hot, and the bolt immediately driven home." (Addition to Manual, Rule 1205, Bulletin 337, Committee XII).

5. "When unused holes are left in treated timber or piling they must be treated with hot preservative and filled with treated plugs. Before driving the plugs must be dipped in hot sealing compound." (Addition to Manual, page 1206, Bulletin 337, Committee XII).

6. "It is recommended that timber be allowed to season for at least sixty days after treatment. It should be piled with spacer strips to give complete air circulation. In addition to other advantages the fire hazard is greatly reduced when treated material is allowed to season about sixty days after treatment. It has been demonstrated that seasoned creosoted material is more resistant to fire than either seasoned untreated or freshly creosoted material." (Manual, page 1275, Committee XVII).

7. "Creosoted timber piled for seasoning or storage should be sheltered as much as possible from direct rays of the sun. Cross sticks should be placed sufficiently close to prevent long timbers or those of small section from sagging and becoming crooked, and every care should be taken to prevent the checking which exposes untreated wood. The top layers of stacked timbers should be covered with sand or dirt to the depth of not less than one-half inch as protection from the sun, and all grass or rubbish should be cleaned from under and around the stacked material to lessen the danger from fire." (Manual, page 1275, Committee XVII).

8. "Creosoted lumber and particularly long or heavy timbers which have been framed prior to treatment should be stacked with special care to avoid warping or distortion while the material is in storage." (Manual, page 1277, Committee XVII).

9. "In handling treated material, extreme care should be used to avoid damage to the edges of the timbers or breaking through the portions penetrated by the treatment and exposing untreated wood. The use of peavies, canthooks, timber dogs, pickaroons, lug hooks, or other pointed tools on treated lumber should be absolutely prohibited." (Manual, page 1275, Committee XVII).

10. Care should be exercised in the proper placing of creosoted caps to obtain long life or service. If season checks have developed more in one face than in the other, that face should be placed down to prevent infection from moisture entering through such season checks.

11. "Sway braces should be fitted from the bottom and any cutting to length found necessary should be at the top. The cut should then be treated with hot creosote, creosote and bridge cement or roofing pitch and fabric as necessary to protect it from the weather." (Manual, page 1276, Committee XVII).

12. "Where the piles in a bent vary in size or are out of line filler blocks shall be used between the braces and piles, securely fastened and faced to obtain a bearing against all piles. Treated filler blocks shall be used with treated braces." (Addition to Manual, Rule 1214, Bulletin 337, Committee XII).

PILING

1. Treated piling placed in storage yards should be carefully stacked. Consideration should be given in method of stacking to allow access of water throughout the stacks that fires may be readily extinguished.

2. Piling should be yarded or stored with entire length at rest which prevents sagging and bends, thus eliminating danger from fracture when driven.

3. When stacked on Right of Way at location of bridge, and if not used promptly, they should be stacked in area free of dead grass or other combustible materials.

4. It is necessary that piling be driven to full resistance which insures a finished structure which holds firm in service with no settlement of bents, and it is equally important such driving be accomplished without injury to the material.

5. "The use of dogs may be employed in rafting piles provided these are placed within one foot of the head or four feet of the tip. Rope slings should be used for unloading and handling. Tongs may be used when confined to the ends as outlined above for lifting so that slings may be placed." (Manual, page 1275, Committee XVII). "A sharp pointed tool should not be used to turn a pile in the gins of the driver. This can be done with a spud and sling. Piles should not be bored for staging. For piling driven in water or with the cut off high above the ground, staging clamps may be used. These may be made of two flat bars, bent to semi-circles and bolted together around the pile. A tail turns up at one end of the iron and projects sufficiently to carry the supporting timber on which the staging plank is laid." (Manual, page 1276, Committee XVII).

6. "All treated pile cut offs and chamfered tops where the piles project beyond the caps should be saturated with hot creosote by repeated applications, and then daubed with hot asphaltum or a mixture of creosote and roofing pitch mixed to a vaseline-like consistency, and swabbed in with a long-handled brush. For chamfered tops it is recommended that suitable fabric be embedded in the hot asphaltum, or roofing pitch

and creosote, and that the outside of this fabric be given an additional coating of the waterproofing material." (Manual, page 1276, Committee XVII).

7. "Holes bored for drift pins should be $\frac{1}{16}$-inch smaller than the drift. This is not recommended for sway brace bolts, as the thread of the bolt has a tendency to sliver the pile on the opposite side. Where possible holes bored in creosoted material should be filled with hot creosote followed by a mixture of creosote and roofing pitch. After the bolt is driven a portion of the pitch creosote mixture should be placed under the washers at both ends of the bolt which, when the bolt is tightened, gives a water tight job under the washers.

"Pitch can usually be worked in between the timbers before tightening to give further protection. With proper care, decay from sway brace bolt holes can be practically eliminated."

"Any holes that may be made either in top or side surfaces and which are not used should be plugged with treated material. The plug should be dipped in creosote and driven to the bottom of the hole. Holes, abrasions, or checks too large to be plugged should be treated with hot creosote and filled with the mixture of creosote and roofing pitch. This may then be protected by sheet copper held in place with copper nails or by special roofing material laid with the weather side out and coated with the pitch mastic on the outside."

"Bridge crews handling creosoted piling and other creosoted material should keep on hand a supply of creosote, bridge cement, or roofing pitch, saturated fabric, and creosoted shimming and plugging material." (Manual, page 1276, Committee XVII).

8. Treated piling or timbers should not be cut or punctured when inspecting same. When there are indications of decay in interior of piling or timbers, same should be bored, care being taken to swab the holes with preservative and plug same with creosoted plugs.

TREATED SWITCH TIES

1. The rules recommended for proper protection of cross ties will also apply to switch ties.

2. Care should be taken in ordering switch ties of proper length so that they may be placed in accordance with standard plan and prevent damage to treated wood by cutting back to lengths required.

3. Switch ties located in switches subjected to excessive operation should be of such quality to withstand the severe mechanical wear, especially turnouts in heavy switching yard leads.

TREATED SIGNAL TIMBER AND TRUNKING

1. All timber should be cut to length and framed prior to treatment because cutting the material after treatment shortens its life. If it is necessary to cut any treated timber, it should be given at least two coats of hot creosote.

2. Trunking and capping treated with creosote or other preservative should be stored under cover whenever practicable to prevent damage by splitting, excessive checking, or warping. If unable to store under cover, it should be close piled and covered with soil to retard evaporation of preservative and warpage of material at top of pile.

TREATED TELEGRAPH POLES

1. To obtain maximum life service it is necessary to avoid gaining and boring of poles after treatment. They should be gained for cross arms, roofed, if specified, and all necessary holes bored prior to treatment as indicated by standard plan. All gains should be cut accurately and parallel so that cross arms will be in vertical alignment, thus eliminating any necessity of having to regain or bore into the treated wood.

2. After treatment poles should be carefully handled so that treatment is not punctured by grab hooks or fractured by impact. When possible, poles should be unloaded by crane or derrick.

3. All poles should have treatment of sufficient depth so that lineman's climbers will not penetrate through the treated wood which may cause infection and decay.

4. Poles in service should have grass and weeds cleared over sufficient area to prevent burning or damage by excessive heat which would cause creosote to exude from pole when overheated.

5. If necessary that any poles be framed or bored in the field, all newly framed or bored surfaces should be protected with applications of hot creosote.

Conclusion

Your Committee recommends that this report be received as information and the subject continued with the recommendation to the Committee on Outline of Work that collaboration of Committees III—Ties, VII—Wooden Bridges and Trestles and XVII—Wood Preservation be directed with Committee XII—Rules and Organization to the end that approved rules be published in the Manual under the jurisdiction of Committee XII.

APPENDIX H

(8) SERVICE TEST RECORDS OF STRUCTURAL TIMBER INCLUDING PILING

C. C. Cook, Chairman, Sub-Committee; Wm. G. Atwood, R. S. Belcher, G. M. Cornell, E. A. Craft, E. B. Fulks, G. P. MacLaren, F. D. Mattos, L. J. Reiser, Dr. Hermann von Schrenk, T. H. Strate.

In response to circular letter of July 6, 1932, replies were received from 16 railroads listing a total of 100 bridges and trestles with data relating to service life according to the form prescribed by the Sub-Committee.

Replies were received from a total of 32 railroads, the other 16 advising generally that they had but few treated timber structures old enough to give useful record, and had no exceptional data relating to service of untreated structures. Two roads advised they had no permanent timber structures on main tracks.

From the replies there were selected one structure from each railroad as near typical of the experience of the whole number reported for the particular group as could be determined. The groups for which data were requested and are hereafter published, covered timber structures:

(a) Treated, that have given outstanding service.
(b) Treated, that have failed or shown serious defects.
(c) Untreated, that have given outstanding service.
(d) Untreated, that have failed or shown serious defects.

It is to be recognized that the responding carriers gave data on but a portion of the number of structures existing on their lines,—the number reported ranging from a minimum of one to a maximum of sixteen for individual carriers. The Committee desiring to present data both indicative and relative as to the service of structural timber, treated and untreated, has made further selection for publication purposes, which are considered adequate and representative, at least within the limits of the character of structures indicated by their descriptions.

Naturally all varieties of timbers, their treatments and conditions of their service found in the States and Canada are not covered. However, to the extent that the tables include two or more structures of similar characteristics in respect to these elements, there may be deduced useful and interesting information.

Most notable in the replies received were the preponderating number of treated timber structures reported as giving outstanding service. Where their ages were limited by the comparatively recent use of treated timber, the excellence reported was reflected in the condition which required little if any renewal after a period of years that would have resulted in complete renewal of the structures had they been of untreated material.

Second, in the group of treated structures where failures were recorded, it was generally attributed to failure to give adequate protection to untreated surfaces exposed in field framing of members.

The relatively large number of treated structures giving outstanding service shown in the tables is a reflection of the number of that character included in the reports of the responding carriers.

Specific attention is directed to the three structures of treated timber that showed early failure and to the definite information in respect to the causes which arose from failure to give adequate protection to untreated surfaces exposed by field framing.

There were but five failures in this group of treated timber structures reported; the three quoted in the tables give information representative of the kind of failures and their causes.

Similarly, a limited number of untreated timber structures giving outstanding service were reported. In an additional instance, the responding carrier in stating that the average life of untreated structures (as taken from the record of 15 structures) was found to be nine years, advised further that it was considered economical to use untreated timber. Presumably this arose from the proximity to site and low first cost of the untreated timber.

The tabulations in this group of untreated timber include three structures of woods notably long-lived, viz.,—long leaf yellow pine, oak and redwood. They doubtless were outstanding in their service and it would probably not be inaccurate to say also that they were exceptional. A study of their descriptions as to character of structure, location and probability of delivery of a prime grade of timber at the period of its installation may suggest it.

One other structure of untreated douglas fir located in Northern territory, representative of somewhat similar service of eight structures of the same timber reported by that line, is included. About twenty years' life had been secured from these structures before entire renewal was needed; at that time most of the original timber still was in the structure.

No stress was placed upon indications in the group of "untreated structures that failed or showed serious defects". It was evidently of general acceptance that structures of untreated timber were inferior and were justified only where favorable conditions as to climate, soil, cost, restricted speeds, and other limits of service prevailed. One or more of such structures however, were selected for the tabulations in order to provide relative data as to life and to indicate the limits of their service.

There is shown at the end of the tabulation for each structure, the percentages of certain main members removed and found defective. And, as a matter of concise conclusion, these are summarized as a final figure into percentage of the whole structure removed and found defective.

Such percentages, particularly as relating to the whole structure, were not always completely supplied by the respondents in the form shown. The data, being made available for members, however, could readily and without practical error be translated into a percentage of the whole structure.

This provided at a glance the approximate condition of the structure as it existed as noted in the report. Particularly in respect to treated structures whose life though now well extended to 20 years more or less are without serious or even apparent defect, this information is valuably indicative. It should not, however, be construed as a mathematical representation of the proportions of service life thus far expended. Combined with the history of the particular structure, the data will enable an estimate of probable service life sufficiently accurate for the practical purpose of determining relative economic values.

The extent to which treated timber is used in ballast deck pile trestles and the record as to replacements, including a description of an early renewal account of inade-

quate protection during field framing, is given in the following reply from the Atchison, Topeka and Santa Fe Railway, G. W. Harris, Chief Engineer:

"In 1930, I had an inspection made of a number of ballast deck pile trestles that were built during the period 1899 to 1910. These structures were found to be in excellent condition, and the records show that no repairs had been required on a number of the trestles, including some that had been in service for over twenty-five years, and where repairs had been necessary, the maintenance had been confined mostly to the replacement of caps, ballast curbs and the placing of shore piling.

Bridge 369–A, included in the tables, gives the service record of one of the oldest structures and is typical of the performance of our long service ballast deck timber trestles. The latest bridge inspection shows the need for some minor repairs, but this is to be expected in a structure that has already rendered thirty-three years of service. It is of interest to note that none of the stringers has been replaced to date.

It might be of interest to your Committee to know that as of December 31, 1930, we had in service ballast deck timber trestles aggregating 287,321 single track feet. The renewal of this type has been very limited, the replacements being as follows:

Cause of Replacement	*Number of Bridges*	*Average Age–Years*
1. Destroyed by fire	9	11
2. Washouts, inadequate waterway and lack of penetration	22	12
3. Abandoned—opening filled	8	19
4. Grade revision	2	22
5. Abandoned account line change	11	18
6. Change in type of structure	14	15
7. Early failure	19	22

In 1925, when the first replacements were necessary account early failure, I had inspection made of the failed piling and timber, and it was developed that early decay was not due to improper or inadequate treatment, but was caused by abuse of the treated timber when the structures were erected. The history of one of these failures is given in the table of "Structures of Treated Timber Showing Serious Defects or Failed" —Bridge 51–B, and the comments which here follow:

Reason for Early Failure

Inspection developed that early failure was not due to improper or inadequate treatment but was caused by following construction methods that proved detrimental. Proper care was not exercised in protecting the untreated portion of piling and timber exposed by cutting and boring in the field. The causes of failure of piling were:—

(1) Decay of the untreated interior of the pile, starting under the cap on account of the cut-offs not being properly protected.
(2) Cuts made for sway and sash braces in some instances into untreated portion of the timber which were not thoroughly protected with creosote when the gaen was made.
(3) Decay originating in bolt holes, due to the entrance of moisture; this decay following the fiber of the untreated interior of the pile.

A few years after this trestle was built in 1903, System standard practice was adopted, to coat the tops of piles with hot creosote, two applications of heavy road oil and then cover with a 2-ply sheet of Elaterite, Rubberoid of Paroid roofing fastened with roofing nails, the roofing trimmed to the exact size of the pile. This protection has practically eliminated the type of failure described as Item (1).

The adoption of the use of filler blocks in applying sway and sash bracing has stopped the gaening of piling and failures classified as Item (2) have been overcome.

This inspection developed the necessity of protecting the untreated interior of piling and timber exposed in boring bolt holes, so in 1926 System practice was put into effect of swabbing all bolt holes with several applications of hot creosote. It is thought this treatment will prevent decay, listed as Item (3).

Failure of Stringers

These were classified as follows:

(1) Cutting the stringers to required length after treatment.
(2) Boring of bolt holes without properly treating the exposed untreated timber.

This inspection developed that stringers had decayed at the ends where the timbers were cut to the required length in the field, exposing the untreated wood. The other end of the stringers that had not been cut off were perfectly sound. It is now the practice to cut all stringers that butt on the cap to exact length before treatment and with careful driving and jacking of bents, it is unnecessary to trim any sticks on the ground. This will eliminate failures, Item (1).

As stated above, all bolt holes are now given thorough treatment.

Failure of Caps

With few exceptions, the caps in the 1903 structure were in excellent condition; those showing decay on account of moisture reaching the untreated interior through bolt holes and checks. All bolt holes are now given careful treatment and this precaution and also the use of larger caps, it is hoped, will overcome the failure of caps."

The oldest large trestle built of creosoted timber of which the Committee received record, is the open deck treated timber trestle, 5.82 miles, on the Southern Railway crossing Lake Pontchartrain. The record for comparative purposes is included in the table of "Structures of Treated Timber giving Outstanding Service". The complete history and record as supplied by B. Herman, Chief Engineer, being of exceptional interest, is quoted below:

Lake Pontchartrain Trestle

Location:	Lake Pontchartrain, MP 172.18 to MP 178.0.
Near:	New Orleans, La.
Description:	Open deck, treated timber trestle. Protected from fire by thin layer of gravel on 1½" untreated cypress plank floor between ties.
Length:	5.82 miles.
No. of Spans:	Originally there were 2014—15′ spans in the present length of trestle and two 250-ft. swing draw spans. With intermediate bents driven as part of a strengthening program (1927 to 1929) there are now a total of 3267 bents.
No. of Piles per Bent:	Original construction 4, intermediate bents 6.
Base Rail to Water:	Approximately 11 ft.
Depth of Water:	8 ft. to 14 ft.
Water:	Brackish.
No. of Tracks:	Single.
Year Built:	1883.
Timber:	Treated Pine (except floor).
Preservative:	Creosote—from England, designated as High Grade, but specification is not a matter of record. Our best information is that specifications in those days required a specific gravity of not less than 1.03 and at least 40 per cent Naphthalene distilling off between 210 and 235 degrees C.
Preframing:	None.
Field Precautions:	Cut-offs swabbed with creosote and pitch.

Present Condition

Date of Inspection: November 17, 1931.

Age of Structure: 48 years on inspection date.

Ties: All ties have been renewed—some several times, on account of mechanical wear.

Stringers: Originally 3 ply—7″ × 16″ under each rail—in 1905 an additional 8″ × 16″ stringer was placed under each rail to take care of increased loads. Approximately 200 of the original stringers have been replaced account of decay, or approximately 2½ per cent. Present annual rate of renewal is .4 per cent. Stringers taken out for test purposes reveal high strength. Tests in 1928 show no decrease in strength from results of tests made in 1909 and 1912.

Piling and Caps: Of the 2014 original bents 603 are still in service, approximately 1100 have been cut off and frame bents placed on the stubs and the remainder have two or more piles cut off and frame posts placed on the stubs. Of the 1100 bents with all piles cut off, approximately 325 were rebuilt because of damage by fire in 1885 only two years after the trestle was completed. Caps are replaced principally when piles are cut down although some have been replaced separately due to crushing or decay.

Remarks: Stringers are in excellent condition, showing no appreciable decay after 48 years service.
Piles are not attacked by marine borers except near the south shore. Piles replaced decayed principally at the cut-off.

Percent defective and removed:

Ties	100 per cent	
Stringers	2½ per cent	plus or minus
Piles	60 per cent	" " "
Structure Approximately	50 per cent	"

Conclusions

The data given in the tables, though necessarily limited by need for conservation of space, is selected as typical of structures of the various kinds of woods and treatment shown and thus as indicative of the service given.

Generally it is evident that creosoted timber trestles give prospect of life two or more times that secured from untreated timber, unless the latter is of timber by nature resistive to decay, or it is in structures where service requirements and climatic effects are moderate or light.

In creosoted timber structures that have shown early failures, the record shows them to have been caused by inadequate protection of surfaces exposed by field cut-offs, borings and destructive handling. Such defects limit the life of creosoted timber irrespective of its kind, whether pine, fir, cedar, oak or other timber of structural grade susceptible of treatment.

Structures of untreated timber are generally not considered to be economic except where light service conditions, nearby supply and low costs prevail.

Recommendation

Your Committee recommends that the "Conclusions" shown at the end of this report be accepted for publication in the Manual and that the remainder of the report be accepted as information and the subject discontinued.

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quately protected.

IVE OR/AND REMOVED	10 years - PILING.....40% ±	25 years - STRUCTURE.....100%	ective; PILES.....14% CAPS.....13%

—— SERVICE TEST RECORDS OF STRUCTURAL TIMBER ——

STRUCTURES OF TREATED TIMBER GIVING OUTSTANDING SERVICE

SERVICE DATA	C. R. & I. R.R.	A. C. L. R.R.	Southern Pacific Texas & New Orleans R.R.	L. V. R.R.	C.M.&St.P. R.R.	SOUTHERN R.R.	A.T.&S.F.Ry.	Union Pacific	Central of Ga.	Sou. Pacific	Sou. Pacific	New York Central	Baltimore and Ohio
LOCATION: Nearest Town	Wymore, Neb.	Dupont, Ga.	Crosby, Texas	Auburn Lookout, Pa.	Servia, Wash.	Lake Pontchartrain Trestle New Orleans, La.	Sedan Lake, Mo.	Somana, Kan.	Hatchechubbee, Ala	Gotel, Col.	Sonoita, Ariz.	River Rouge, Mich.	Vincennes, Ind.
TRESTLE: Type	Creosoted ballast deck pile trestle	Creosoted ballast deck pile trestle	Creosoted ballast deck pile trestle	Creosoted ballast deck pile trestle	Creosoted open deck pile trestle	Creosoted open deck pile trestle	Creosoted ballast deck pile trestle	Pile trestle (piling only treated)	Pile Trestle	Creosoted ballast deck pile trestle	Creosoted ballast deck pile trestle	Creosoted ballast deck pile trestle	Creosoted ballast deck pile trestle
Length	98'	201'	256'	128'	80'	5,825 feet	993'	475'	144'	75'	135'	98'	510'
No. of spans	7	30	15	9	6	(Orig'l - 2014 spans (Since '29-2256 "	72	72	12	5	9	8	36
Height - max.	26'		24'					18'	17'	7'	34'	17'	17'
Max. span	9'		6'					17'	4'	7'	5'	5'	5'
No. of tracks	18'	Two	16' Single	12' Single	10'6 Single	11' B.of S.to L.water Single	22' Single (N.S. since 1910)	17.5' Single	18' Single	7' Single	30' Single	15' Single	12' Single
THE BUILT	1905	1921	1890	1915	1915	1883	1899	1904-5	1913	1896	1898	1910	1910
TIMBER	Creosoted; L.L.T.P. for all lumber and piling	Creosoted; Piling L.L.T.P. Caps " Stringers " Floor Pl'kg " Guard Rail "	Creosoted; Piling T.P. Caps T.P. Stringers " Bracing " Curb "	Creosoted; Piling L.L.T.P Caps " Stringers " Pl.plank " Bracing " Curb "	Creosoted; Piling D.Fir Caps " Stringers " G.-rail " Ties "	Creosoted; Piling Y.P. Stringers " Ties "	Creosoted: All So. Y.P.	Creosoted: Piling - L. L. T. P.	Creosoted; Piling L.L.T.P. Caps " Stringers " Bracing " Untreated: Ties Cypress G.Timber "	Douglas Fir	Douglas Fir	Yellow Pine	Creosoted; Piling Oak Caps L.L.T.P. Stringers " Pl.plank " Bracing " Curb "
TREATMENT: Preservative	Creosote (Imptd.)	Creosote - Grade 1	Creosote	Creosote - Grade 1	Creosote	Creosote (Imported)	Creosote - piles caps, strs. and bracing. Lime Tannin -G.B	Creosote	Creosote	Creosote	Creosote	Creosote	Creosote -Grade 1
Process	Full cell	Full cell	Full cell	Empty cell	Full cell (Boulton)		Full cell	Full cell	Full cell	Issaca-Curtis Boiling in vacuum	Issaca-Curtis Boiling in vacuum	Lowry	Empty cell (Lowry)
Absorption, net	10 lbs. per cu.ft	18-20# per cu.ft.	(No record)	10# per cu.ft. Single	12# per cu.ft. Single		About 15# of a light grade creosote.		17.5# per cu.ft	10-12# per cu.ft.	10-12# per cu.ft.	12# per cu.ft.	Piling 10.6# cu.ft. L.L.T.P. 9.2# "
PRE-FABRICATION: Plan reference	None		None	None	Yes	None	None	None	None	Caps and strs. cut to length	Caps and strs. cut to length	Caps and strs. dressed to uniform depth	None
PRE-FABRICATION: Character	Lumber and piling cut off, bored and otherwise framed in field as required.	Piles cut off; caps stringers and guard rails bored.	Piling cut off and bored; caps and stringers bored and drift bolted; bracing bored.	Piling cut off and bored, caps and bracing bored.	All timber pre-framed and bored except braces and bolt holes in piles	Piling cut off	Piles-cut off and bored Caps - bored Stringers - bored	Piles cut off and bored.	Piles - cut off Caps - bored and dr.bolted Stringers - bored and bolted.	Piles cut to height; all sway brace and drift bolt holes bored.	Piles cut to height; all sway brace and drift bolt holes bored.	Piling - cut off and bored for bracing. Caps - drift bolted. Stringers - drift bolted to caps.	Piling - cut off and bored for bracing. Caps - bored, dr. bolted. Stringers - outer - bored int.-dr.bolted. Bracing - bored.
Treatment precautions	No precautions to protect exposed surfaces.	Tops of piles and bolt holes painted three times with creosote.	Cut-offs swabbed with creosote.	Cut-offs swabbed with creosote. Bolt holes not treated.	Field cuts treated with hot creosote.	Cut-offs swabbed with creosote and pitch.	Not known.	None	Cut-offs swabbed with hot creosote.	Pile heads saturated with hot creosote, then coated with hot asphalt.	Pile heads saturated with hot creosote, then coated with hot asphalt.	Cut-offs and bolt holes swabbed with creosote	Cut-offs and bolt holes swabbed with creosote
PRESENT INSPECTION: Date of inspection		April 27, 1932	May 9, 1932	July 1932	Sept. 23, 1932	November 17,1931	April 28, 1932	June 1932	July 1932	1932	1932	May 13, 1932	December 10, 1931
AGE OF STRUCTURE	28 YEARS	11 YEARS	42 YEARS	17 YEARS	17 YEARS	48 YEARS	33 YEARS	27 YEARS	19 YEARS	36 YEARS	34 YEARS	22 YEARS	22 YEARS
Defects	One cap removed in 1931; pile crushing into it. 10 piles replaced. 12 " show signs of decay.	9 piles and three caps marked 1932 for removal	All old piles and posts soft; 18% bad. 75% caps soft. 25% stringers bad; other stringers soft. Guard rail an. bulkheads soft.	No defects	Piling - O.K. Caps - 2 bolted sect.checking. Stringers - 6 either checked or warped. Ties - 12 checked 2 fallout	Piling and Caps; Insmidio.....603 Replacedby fr.Beats to 9. lines - (a) Active '85 325 (b) Ballastic Sale. .... 775 Replacement of posts insert.. 311 2014 Stringers; Replaced 200 or 8% Tests in 1928 show high strength of material.	Repairs to date: Piles 8 '17to21 "(ahn)12 " " 1 1925 Caps 1 '17to21 " 1 1926 " 3 1928 " 4 1930 " 19 1931 Planks 4 1931 Inst. Rail - All replaced with creosoted ties not known.	23 piles - decay ground line and lower bolt holes. 2 piles - post 9 " -heart Decay, in tops account inadequate protection.	2 piles - heart decay. 2 caps - replaced account decay.	One pile split slightly, otherwise good.	[illegible]	None	None
REMARKS	Strs.,deck,planking and fenders in good condition; replacements. Post of 40 original piles are good. Proposed to replace all old piling with frame bents 1932.		This bridge re-inforced for heavier loading using 4-post intermediate bents.	No repairs required in 17 years.	Only repair work has been lining and surfacing; also bolting two checked caps.	Stringers in excellent cond. showing no appreciable decay after 48 years service. piles replaced decayed principally, at out off.	Structure raised 4 ft. on pony bents in 1910. 5 8.6" posts replaced '21. Some settlement in 16 bents.	Piling defects due to splits at ground line or not swabbed at cut-offs & bolt holes in bracing.	Untreated cypress ties and guard rail replaced in 1926 with creosoted material.		No repairs have been necessary on this structure since its construction.	Piling shows no decay. All pine timbers excellent and still saturated with creosote.	Oak piling shows no decay. All pine timber excellent and still saturated with creosote
PER CENT DEFECTIVE: (Piling, Caps, Stringers)	Percent defective; Piling 60% Caps.....0% Stringers...0 STRUCTURE...30%	Percent defective; Piling.....6% Caps.....10% STRUCTURE.... 8%	Percent defective; Piling.....16% Caps.....75% Stringers...100% Curb.....100% STRUCTURE.... 80%	Percent defective; STRUCTURE....0%	Percent defective; 1 cap badly checked. STRUCTURE.....0%	Percent defective; sec removed; Piles.....60% Stringers...8.5% Ties.....100% STRUCTURE... 50%	Percent defective and removed; Piling.....6% Caps.....40% STRUCTURE... 6%	Percent defective; PILING...17% (Remainder of trestle is untreated)	Percent defective: Piling.....5.6% Caps.....15.6% STRUCTURE... 8.6% (excl. ties & g.r.)	Percent defective; STRUCTURE..0%	Percent defective: STRUCTURE...0%	Percent defective; STRUCTURE.....0%	Percent defective; STRUCTURE....0%

SERVICE TEST RECORDS OF STRUCTURAL TIMBER

STRUCTURES OF TREATED TIMBER SHOWING SERIOUS DEFECTS OR FAILED

SERVICE DATA	C. B. & Q. R.R.	A. T. & S. F. Ry. Co.--Portion of the A.T.& S.F.Rwy.System	CENTRAL OF GEORGIA
	Bridge No. 45.58	Bridge No. 51-B	Bridge No. 101.6
LOCATION: Nearest Town	Rulo, Neb.	Dallas, Tex.	Wadley, Ga.
DESCRIPTION Type Length No. of spans Height - Max. Min. Aver. No. of tracks	Open deck pile trestle. Record kept only on 41 piling 50' to 60' long.	Creosoted ballast deck pile trestle 890 lin. ft. 64 24 ft. Single	Creosoted open deck pile trestle - 6-pile. 189 lin. ft. 16 22 ft. 22 ft. 22 ft. Single
YEAR BUILT	1922	1903	1915
TIMBER	Creosoted Cypress piling	Southern Yellow Pine	Treated; Piling.....Y. Pine Caps..... do Stringers... do Bracing..... do
TREATMENT Preservative Process Absorption, net	Creosote - Grade 1. Full cell 25 pcs. - 7.86 lb.per c.ft. 16 " - 8.61 " " "	Creosote Full c-ll 10 lbs. per cu.ft.	Creosote - Grade 1 Full cell Piling: 17.36 lbs. per cu.ft.
PRE-FRAMING Plan reference	None	None	
FIELD FRAMING Character	Piles cut off and bored.	Piling - cut off and bored for drift and sway bracebolts. Caps - bored for drift, sway brace and guard rail bolts. Stringers - bored for drift and guard rail bolts; cut to required length.	Piling - cut off. Caps - bored and drift bolted. Stringers - bored and bolted. Bracing - bored and bolted.
Treatment precautions	Cut-offs painted with hot creosote and covered with heavy roofing paper. Bolt holes poured full with hot creosote.		Cut-offs swabbed with hot creosote.
PRESENT CONDITION Date of inspection		Structure renewed in 1926.	May 1926
AGE OF STRUCTURE	10 years	23 years	11 years
Defects	Of 41 piles, 3 were spliced in 1928; 10 more were spliced in 1931. Several others are decayed on inside. Outer surface appears sound. Decay detected only by boring.	Failure of piling due to: (1) Decay of untreated interior at cut-off - not properly protected. (2) Gaens for bracing exposed untreated areas - not thoroughly protected. (3) Decay in bolt holes due to moisture reaching untreated fibre ofwood. Failure of stringers due to: (1) Cutting to lengthafter treatment. (2) Boring after treatment without properly treating exposed untreated areas.	13 piles, heart decay 2 caps to be renewed account of decay.
REMARKS	Material was not sufficiently seasoned to permit satisfactory treatment.	See body of report for description of Santa Fe's practice which eliminated failures from above causes.	Piles rotting from top down; cut-offs not adequately protected.
PER CENT DEFECTIVE OR/AND REMOVED	Per cent defective after 10 years - PILING.....40% ±	Per cent defective after 23 years - STRUCTURE.....100%	Per cent defective; PILES.....14% CAPS.....13%

----- SERVICE TEST RECORDS OF STRUCTURAL TIMBER -----

STRUCTURES OF UNTREATED TIMBER GIVING OUTSTANDING SERVICE

SERVICE DATA	Southern Pacific	Pennsylvania	New York Central	Canadian Pacific
	Bridge No. 97-D	Bridge No.- Coal Tr.	Bridge No. L-14	Bridge No. 4.06
LOCATION: Nearest Town	Bypass, Cal.	Harrisburg, Pa.	Lockport, N.Y.	Swift Current, Sask.
DESCRIPTION: Type	Open deck pile trestle (4-pile bents, reinforced with 2 add'l. piles each.)	Timber coal trestle	Open deck pile trestle	Pile and timber trestle, 1906 Standard
Length	3845 lin. ft.	650 lin. ft.	90 lin. ft.	195 lin. ft.
No. of spans	140	54	6	13
Height - Max.	22'	40'	10'	50'
Min.	22'	12'	2'	5'
Aver.	22'	26'	6'	30'
No. of tracks	One	One	One	One
YEAR BUILT	Piles 2-3-4-5..1889 " 1-6.....1926	1905	1915	1911
TIMBER	Piles 2-3-4-5, Round redwood. Piles 1 and 6, Cedar Deck,- Douglas Fir	Sills.....L.L.Y.P. Posts..... do Bracing... do Caps..... do Deck..... do	Piles.....Oak Caps.....L.L.Y.P. Stringers. do Deck..... do	Piling.....Douglas Fir Caps..... do Stringers.. do Bracing.... do Guard Rail. do Posts..... do Sills..... do
TREATMENT Preservative	None	None	None	None
PRE-FRAMING Plan reference	None	None	None	
FIELD FRAMING Character	Piles cut to height, Sway brace end drift bolt holes bored.	Hand	Piles - cut off and bored for bolts & drifts. Caps - bored for drifts and braces. Braces - cut and bored for bolts.	
PRESENT CONDITION Date of inspection	1931	August 20, 1932	August, 1932	May, 1932
AGE OF STRUCTURE	42 YEARS	29 YEARS	19 YEARS	21 YEARS
Defects	28 of the 1889 piles were redriven in 1926 and 1 pile spliced. Otherwise good.	Bracing, sills, caps, legs and stringers showing signs of deterioration,- crushing and general deterioration.	Piling is bad and life of the trestle about gone.	All timber and piles decaying - To be totally replaced in 1933.
REMARKS	The deck has been repaired from time to time and was given a thorough overhauling in 1918.	This structure subject to all weather conditions, and smoke from engines; also very hard use. Current running repairs have been made from time to time, but no general overhauling has taken place.		1923 - Piles redriven and cross capped. 1925 - Bents 1-2-14 redriven due to fill sliding. 1927 - 4 str. 2 sills, 17 ties, 4 pos. g.r. renewed. 1929 - Bents 12-13 redriven due to fill sliding. 1930 - 4 str., 10 sills, 20 ties, 1 post renewed 1931 - 2 str., 5 caps, 12 ties renewed. 1932 - 4 str., 5 caps, 24 ties, 6 sills, 6 pos. g.r. renewed.
PER CENT DEFECTIVE OR/AND REMOVED	REDWOOD PILING....3%	Removed in repairs at various times....10% STRUCTURE.....25%	Piling..... 90% Caps..... 90% Stringers.... 85% Deck..... 90% STRUCTURE.....90%	About 25% of timber removed. Balance of timber and piles about done. STRUCTURE.....100% ±

----- SERVICE TEST RECORDS OF STRUCTURAL TIMBER -----

STRUCTURES OF UNTREATED TIMBER SHOWING SERIOUS DEFECTS OR FAILED

SERVICE DATA	New York Central	New York Central	Southern Pacific
	Bridge No.- Coal Trestle	Bridge No.- Trestle (For stone sand & gravel)	Bridge No. 288-D
LOCATION: Nearest Town	Watertown, N.Y.	South Utica, N.Y.	Orris, Cal.
DESCRIPTION: Type	Framed timber trestle open deck, partly housed, masonry substructure.	Framed timber trestle open deck, concrete substructure	Open deck trestle 5-pile bents
Length	577 lin. ft.	17 lin. ft.	195 lin. ft.
No. of spans	48		13
Height - Max.	32'6"	22'	35'
Min.	7'4"	22'	35'
Aver.	20'	22'	35'
No. of tracks	Two	One	One
YEAR BUILT	1919 (Replacements in 1927 and 1930)	1920	1916
TIMBER	L. L. Y. P. (Original stated to be of not the best grade)	Fir - Selected grade	5-pile bents - Cedar Deck - - - - - Douglas Fir
TREATMENT Preservative	None	None	None
PRE-FRAMING Plan reference	None	None	None
FIELD FRAMING Character	Original by contract (Fair)	Usual cutting and boring. Caps - drifted to posts. Posts - dowelled to sills. Stringers - drifted to caps and bolted together with spacing blocks. Braces - bolted.	Piles cut to height. All sway brace and drift bolt holes bored.
PRESENT CONDITION Date of inspection	1932	October 1, 1932	1927
AGE OF STRUCTURE	8 years to 1927 13 " " date	12 Years	Piles - 12 Years
Defects	Decayed timber	Posts in exposed bents are decayed through under brace plank. Posts and sills in bents covered with stone, sand, etc., decayed completely.	Piles decayed badly just below the ground surface. Piles were then cut off in 1925 and 1926 and supported on sills.
REMARKS	Above refers to the unhoused approach structure. Housed portion in fairly good condition - no renewals.	Trestle taken out of service September 16, 1932 account unsafe	Structure entirely renewed in 1928.
PER CENT DEFECTIVE OR/AND REMOVED	Stringers.....40% Bents.....50% Deck.....100% STRUCTURE.....60%	Stringers.....60% Ties.....70% (Mechanically worn) STRUCTURE.....80% ±	STRUCTURE.....100%

REPORT OF COMMITTEE III—TIES

W. J. Burton, *Chairman;*
R. S. Belcher,
W. C. Bolin,
H. F. Brown,
R. E. Butler,
Doyle Campbell,
E. E. Chapman,
H. R. Clarke,
S. B. Clement,
R. L. Cook,
E. L. Crugar,
H. R. Duncan,
C. F. Ford,
C. W. Greene,
R. M. Jolley,
J. E. King,
C. S. Kirkpatrick,
F. C. Krell,
L. O. Lower,
A. F. Maischaider,
L. T. Nuckols,
John Foley, *Vice-Chairman;*
L. J. Riegler,
S. S. Roberts,
S. E. Shoup,
L. L. Tallyn,
J. W. Tate,
Sverre Thorvaldson,
J. R. Watt,
W. W. Wysor,
R. C. Young,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully presents herewith report covering the following assigned subjects:

(1) Revision of Manual (Appendix A).

(2) Extent of adherence to Standard Specifications (Appendix B).

(3) Substitutes for wooden ties (Appendix C).

(4) Tie renewal averages and costs per maintained mile, securing data from reports to Interstate Commerce Commission (Appendix D).

(5) Recommend standard spacing of spike holes for ties pre-adzed and bored for standard rail sections 90-lb. to 131-lb. inclusive, collaborating with Committees IV—Rail, V—Track, and XVII—Wood Preservation (Appendix E).

(8) A method of predicting tie renewals, including a period of change from untreated to treated ties (Appendix F).

(9) Type of tie plate best adapted for use with pre-adzed ties, collaborating with Committee V—Track (Appendix G).

(10) Economy of use of tie plates which are secured to the tie independently of the rail fastenings, with particular reference to the effect on tie life (Appendix H).

(11) Methods of inspection for renewal of ties, checking thereof, and adherence thereto (Appendix I).

In line with existing instructions, your Committee has elected not to report this year on the following assignments:

(6) Best practice from the manufacture of the tie to its installation in track, collaborating with Committee XVII—Wood Preservation.

(7) Economics of the use of ties longer than 8 ft.

Action Recommended

(1) That the revisions of the Standard Specification for Cross and Switch-Ties proposed in Appendix A be approved for inclusion in the Manual.

(2) That the reports contained in Appendices B, C, D, F, G, H and I be received as information.

(3) That Appendix E be received as information and the subject reassigned by the Board to that committee which is charged with tie plate design.

Respectfully submitted,

The Committee on Ties,
W. J. Burton, *Chairman.*

Bulletin 363, January, 1934.

Appendix A

(1) REVISION OF MANUAL

Specification for Cross-Ties
Specification for Switch-Ties

John Foley, Chairman, Sub-Committee; R. S. Belcher, H. R. Duncan, C. F. Ford, R. M. Jolley, L. T. Nuckols, S. S. Roberts, J. W. Tate, Sverre Thorvaldson.

Difficulties in the applications of the specifications for cross-ties and switch-ties which were anticipated during the discussion of standards ten years ago have not developed to the extent expected. Experience with tie procurement since the standards were adopted in 1926 has shown that the compromises with engineering requirements agreed to then are no longer necessary. Gradually more and more railroads have individually strengthened their specifications by lowering the manufacturing tolerances as the standard of tie produced has been raised generally.

Since the adherence of the railroads to the standards encouraged the manufacturers of ties to apply more careful and skillful workmanship to his product and to take pride in his output, the appropriateness of desirable changes in the specifications is apparent, and the following revisions of the Manual are recommended for the reasons given below:

SPECIFICATION FOR CROSS-TIES (Manual, page 119)
SPECIFICATION FOR SWITCH-TIES (Manual, page 124)

Present Form	*Proposed Form*
Split	**Split**
16. One which is not more than 10 inches long will be allowed, provided a satisfactory anti-splitting device has been properly applied.	16. One which is not more than 5 inches long will be allowed, provided sufficient satisfactory anti-splitting devices have been properly applied.

Whatever split is present in an accepted tie may be expected to extend farther under the stresses of seasoning and traffic. Consequently the acceptance of a split already long enough (in an 8-ft. tie) to reach into the section requiring maximum strength for spiking plates and rails has been poor practice. Under improved manufacturing practice, ties with excessive splits are no longer common, and the tolerance of a split longer than 5 inches is not now advisable.

A single anti-splitting device in an end of a split tie is not always enough to stop its rending. Depending on the kind of wood, size of tie, location of pitch, and other factors, effective arresting of splitting may require two or more irons. The wording of the specification needed changing to permit insistence on enough irons to save the tie.

SPECIFICATION FOR CROSS-TIES (Manual, page 119)

Present Form	*Proposed Form*
Dimensions	**Dimensions**
20. The lengths, thicknesses and widths specified will be considered met by ties 1 inch shorter, and ¼ inch thinner and narrower than the standard sizes. Ties over 1 inch, but not over 2 inches, more in thickness than the maximum ordered will be accepted as one size below the largest tie ordered. Those over 2 inches more in thickness; those over 3 inches more in width; or those over 2 more in length than the maximum ordered will be rejected.	20. The lengths, thicknesses and widths specified are minima for the standard sizes. Ties over 1 inch longer, thicker or wider than the standard size ordered will be rejected.

SPECIFICATION FOR SWITCH-TIES (Manual, page 124)

Present Form	*Proposed Form*
Dimensions	**Dimensions**
20. The lengths, thicknesses and widths specified will be considered met by ties 1 inch shorter and ¼ inch thinner and narrower than the standard sizes. Ties over 1 inch more in thickness, over 3 inches more in width, or over 2 inches more in length than the maximum ordered will be rejected.	20. The lengths, thicknesses and widths specified are minima for the standard sizes. Ties over 1 inch longer, thicker or wider than the standard size ordered will be rejected.

Carelessness alone is responsible for the production of ties shorter than the standard lengths of 8 ft. and 8 ft. 6 in. Since studies of track stresses indicate that ties could advantageously be longer than the present standards, there is solid reason for ceasing to tolerate manufacture which is below normal in regard for good workmanship.

The allowance of ¼ inch which provided for average axmanship and was designed to cover the occasional thin or narrow hewed tie has been used by millmen to justify 100 per cent production of ties with thicknesses and/or width less than the nominal standard thickness.

Now that the majority of ties are given preservative treatment and many of them are adzed, it is more than ever essential that reduction of the standard thicknesses should not be tolerated. The latter shrink anyhow as a result of seasoning preparatory to treatment.

The five standard widths of ties provide for the utilization of all the normal diameters of logs which yield the two standard thicknesses. With a difference of only 1 inch between each successive standard size, a tie now wide enough for one size automatically falls into the next lower size. Since such a tie (within the range of standard widths, but too narrow for a given size) is now thereby rejectable altogether, there is no longer excuse for tolerating a reduction in its width, which is too often deliberate.

The cross-cutting of a tie 6 inches to 10 inches in thickness or width does not require a leeway of 2 inches under the improved manufacturing which now prevails; 1 inch of overlength is ample for careful choppers or sawyers aiming to produce ties with square ends.

The round ties which constitute the class catered to by the admission of 3 inches wider than the maximum standard are expensive in many ways after their acceptance; they occupy valuable car space when shipped, require more freight to be paid, split more while seasoning than narrower ties with less sapwood to shrink, reduce the number of ties handled at one time in teating cylinders, absorb excessive quantities of preservative, and disturb ballast unduly when inserted in track. Closer utilization of logs has greatly reduced the number of such ties produced, and the curtailment of the tolerance in width to 1 inch will be contribution to the conservation of timber.

The recommended revisions of the Specification for Cross-ties necessitate corresponding changes in the illustrations of the "Application of the Specification for Cross-ties (Manual, page 121). In line 4, column 5, the thickness becomes 82 instead of 8″–9″ and the bottom width 9″–12″ instead of 9″–15″; column 6, the thickness 8″ instead of 9″. In line 5, column 6, the width becomes 10″ instead of 12″.

Appendix B

(2) EXTENT OF ADHERENCE TO STANDARD SPECIFICATIONS

John Foley, Chairman, Sub-Committee; R. S. Belcher, Doyle Campbell, H. R. Duncan, C. F. Ford, R. M. Jolley, L. T. Nuckols, S. S. Roberts, J. W. Tate, Sverre Thorvaldson.

During 1933 the consumption and production of ties continued subnormal. The comparatively few railroads accepting freshly-made ties were free from any pressure to depart from the standard specifications, judging by the reports from individual members of the Committee on Ties, who found stocks being replenished with excellent ties wherever they observed them.

The available statistics on the number of cross-ties in the hands of producers show that during the past year they have stocked as many as they have shipped. It is to be hoped that this balance between demand and production can be maintained. Were a situation to develop wherein the requirements of the railroads drained quickly the relatively short supply of stored ties and production did not keep pace with consumption, care should be exercised to see that the improvement in the dimensions and quality of ties due to the application of the standard specifications is not lost as a result of competition for supplies by railroads on the basis of inspection. After the demonstration during the past decade of what can be accomplished by a single standard adhered to with reasonable uniformity, it would be deplorable for railroads to resume the former practice by many of meeting competition in procurement through lowering the quality and size of ties accepted. Competition by means of inspection instead of price does not increase the supply of ties; it induces the producer to overlook slipshod manufacture and thus encourages the making of sub-standard ties. For one railroad to accept as Size 3 a tie which is Size 2 or to accept as sound or solid a tie which is decayed or split in order to appear to be paying a like or lower price seems a senseless procedure, but it was for a long time customary performance whenever the demand for ties exceeded the supply, and the subject is brought up in the hope that history will not repeat itself. There are sufficient sizes of standard ties to permit the railroad desiring to economize to purchase the cheaper smaller sizes. The debauching of inspection is started by the railroads; it is not sought by the producer, for he knows from past experience that its only result is the demoralization of his industry.

In a paper on "Why Close Adherence to Standard Specifications Pays from the Producers' Standpoint", read at the 1933 annual meeting of the Railway Tie Association, its author says: "Still another benefit to be derived by the producer is by holding strictly to the specifications as regards size. If the inspector is tolerant, even to a small degree, and permits ties of undersize to get into the higher size, then the producer will become careless in the manufacture of his timber and will in many instances cut some timber and take a chance; whereas, if he understands that close adherence to specifications regarding sizes will be applied, he will not denude his timberland and will cut only such trees as will work without waste. I might say that the producer and consumer are alike indebted for standard specifications, because of the benefits each derives therefrom, but dealing more directly with the producer, his slogan—similar to that of our good friends, the railroads—might well be 'Stop-Look-Heed' strictly the standard tie specifications, for an 'honest tie is the best policy' ".

Appendix C

(3) SUBSTITUTE TIES

A. F. Maischaider, Chairman, Sub-Committee; R. E. Butler, S. B. Clement, Sverre Thorvaldson, W. W. Wysor, R. C. Young.

REPORTS FROM RAILWAYS MAKING TESTS OF SUBSTITUTE TIES

Atlanta & West Point Railroad

Reported by
Date—

Name of tie	Duke Reinforced Concrete
Location	Louise, Ga.
Date put in track	June 27, 1927
Number put in track	10
Number now in track	
Kind of ballast	Stone and gravel
Weight of rail	90-lb.
Kind of traffic	High speed, heavy service, freight and passenger

Bangor & Aroostook Railroad

Reported by P. C. Newbegin, Chief Engineer
Date—July 29, 1933

Name of tie	Maine Concrete
Location	Hudson, Me.
Date put in track	10—Dec. 11, 1923 59—Aug. 30, 1924
Number put in track	69
Number now in track	63
Kind of ballast	Gravel
Weight of rail	100-lb.*
Kind of traffic	High speed, heavy service, freight and passenger

* Changed from 85-lb. rail in 1930.

Four ties removed May, 1933, account of breaking up and disintegration of concrete under rail seat. When removed, all found to be broken and held together only by the reinforcement. Inspection July, 1933, showed the 63 in track all in good condition except three or four. These showed slight cracking and disintegration under rail seat and will probably have to come out within a year.

Bessemer & Lake Erie Railroad

Reported by F. R. Layng, Chief Engineer
Date—August 2, 1933

Name of tie	Brown
Location	Oakmont, Pa.
Date put in track	1930
Number put in track	1500
Number now in track	1056
Kind of ballast	Slag
Weight of rail	130-lb.
Kind of traffic	Heavy service, exclusively freight

Delaware & Hudson Railroad

Reported by H. S. Clarke, Engineer Maintenance of Way
Date—August 2, 1933

Name of tie	Dalton Steel Tie
Location	All Yards
Date put in track	1927—33
Number put in track	83,186
Number now in track	83,186
Kind of ballast	Cinder
Weight of rail	90-lb.
Kind of traffic	Yard track with light and heavy switching or storage use

Duluth, Missabe & Northern Railroad

Reported by E. H. Dresser, Vice-President and Chief Engineer
Date—August 25, 1933

Missabe Division:		
Name of tie	Carnegie Steel Ties	Kimball Steel Ties
Location	Duluth and Proctor	Virginia, Minn.
Date put in track	1908	1914
Number put in track	22,380	30
Number now in track	18,706	30
Kind of ballast	Crushed Rock	Gravel
Weight of rail	100-lb.	100-lb.
Kind of traffic	High speed, heavy service passenger & freight	Heavy service, exclusively freight

Iron Range Division:		
Name of tie	Carnegie Steel Tie	Hatch Concrete Tie
Location	Various points	Two Harbors, Minn.
Date put in track	1908–09	1923
Number put in track	2,000	11
Number now in track	889	7
Kind of ballast	Gravel	Gravel
Weight of rail	80-lb.	80-lb.
Kind of traffic	Heavy service, exclusively freight	Heavy service, exclusively freight

Elgin, Joliet & Eastern Railway

Reported by Arthur Montzheimer, Chief Engineer
Date—August 3, 1933

Name of tie	Bates Concrete	Carnegie Steel	Carnegie Steel (switch)
Location	Whiting, Ind.	Various	Various
Date put in track	1912	1909–18	1912–27
Number put in track	62	15,514	527,815*
Number now in track	54	3,470	42,662*
Kind of ballast	Crushed rock	Gravel, cinder slag	Gravel, cinder, slag
Weight of rail	85-lb.	85–100-lb.	85–100-lb.
Kind of traffic	Heavy service, exclusively freight		

Los Angeles Railway Corporation

Reported by B. H. Eaton, Engineer Way and Structures
Date—July 28, 1933

Name of tie	MacDonald Concrete
Location	Los Angeles
Date put in track	1911
Number put in track	627
Number now in track	584
Kind of ballast	Solid Concrete
Weight of rail	87-lb.
Kind of traffic	Heavy traffic exclusively passenger

* Linear feet.

Pennsylvania Railroad

Reported by T. J. Skillman, Chief Engineer
Date—August, 1933

Mr. Skillman is of the opinion that, since deterioration is going on at about the same rate per year, a report every four or five years should be satisfactory; hence makes no report at this time.

St. Louis–San Francisco Railway

Reported by F. G. Jonah, Chief Engineer
Date—August 2, 1933

Name of tie	Clark Applegate
Location	Springfield, Mo.
Date put in track	December, 1914
Number put in track	125
Number now in track	90
Kind of ballast	Cinders, gravel, chatts
Weight of rail	85-lb.
Kind of traffic	Heavy service, exclusively freight

The ties are getting very badly corroded and the lugs holding the wooden fillers are pretty weak and in some instances are broken off. Thirty ties were removed during last year on account of complete failure of lugs holding wooden fillers in place.

Southern Pacific Lines

Reported by E. A. Craft, Engineer Maintenance of Way
Date—August 21, 1933

Name of tie	U. S. Indestructible
Location	Eagle Pass, Tex.
Date put in track	1916
Number put in track	23
Number now in track	22
Kind of ballast	Cinder
Weight of rail	80-lb.
Kind of traffic	Main track, light service

Original spiking blocks have been removed, account decay, and have been replaced by blocks made from creosoted ties.

Terminal Railroad Association of St. Louis

Reported by H. J. Pfeifer, Chief Engineer
Date—August 10, 1933

Name of tie	Miller
Location	St. Louis, Mo.
Date put in track	May, 1924
Number put in track	100
Number now in track	100
Kind of ballast	Cinder
Weight of rail	100-lb.
Kind of traffic	Moderately heavy freight and passenger service, medium speed

Ties are in first-class condition, none of them have been removed and no expense of any kind has been incurred in connection with them since installed. Judging by present condition, there is every reason to expect a life of thirty years or more.

SUMMARY OF TESTS OF SUBSTITUTE TIES, NOW IN PROGRESS, 1933

Railroad	Name of Tie	Location	Date Put in	Number Put in	Number Now in	Ballast	Rail Section, Pounds	Traffic
Atlanta & West Point	Duke	Louise, Ga.	1927	10	10	Stone and gravel	90	A
Bangor & Aroostook	Maine	Hudson, Me.	1923–24	69	63	Gravel	100†	A
Bessemer & Lake Erie	Brown	Oakmont, Pa.	1930	1,500	1,056	Slag	130	C
Delaware & Hudson	Dalton Steel	All Yards	1927–33	83,186	83,186	Cinder	90	E & F
Duluth, Missabe & Northern:								
Missabe Division	Carnegie Steel	Various	1908–09	22,380	18,706	Crushed Rock	100	A
	Kimball Steel	Virginia, Minn.	1914	30	30	Gravel	100	C
Iron Range Division	Carnegie Steel	Various	1908–09	2,000	889	Gravel	80	C
	Hatch Concrete	Two Harbors, Minn.	1923	11	7	Gravel	80	C
Elgin, Joliet & Eastern	Bates Concrete	Whiting, Ind.	1912	62	54	Crushed Rock	85	C
	Carnegie Steel	Various	1909–18	15,514	3,470	Gravel, Cinders, Slag	85–100	C
	Carnegie Steel (switch)	Various	1912–27	527,815*	42,662*	Gravel, Cinders, Slag	85–100	C
Los Angeles Railway	McDonald Concrete	Los Angeles, Cal.	1911	4,323	584	Solid Concrete	87	B
Pennsylvania	Riegler Concrete	Emsworth, Pa.	1908	15		Stone	130	A
	Snyder Composite	Pittsburgh Div. Yds.	1907	2,255		Cinder	100	F
	Brown Concrete	Aspinwall, Pa.	1925	100	No report for 1933	Cinder	130	C
		Hayes, Pa.	1925	410		Stone	130	C
		Monongahela, Pa.	1927	2,516		Cinder	130	A
		Wilkinsburg, Pa.	1928	1,861		Stone	130	E
		Pitcairn, Pa.	1928	3,336		Cinder	130	C
		Derry, Pa.	1927	1,978		Cinder	130	E
		Compitt Jct., Pa.	1927	2,843		Stone	130	C
		Tunnelton, Pa.	1928	2,385		Cinder	130	A
		Bellwood, Pa.	1927	3,006		Stone	130	C
		Highspire, Pa.	1927	1,486		Cinder	130	C
		M.P. 31-A. & S. Branch	1927	517		Cinder	130	C
		Haines, Pa.,	1927	970		Stone	130	A
		Conowingo, Pa.	1927	1,986		Stone	130	A
		Octoraro, Pa.	1927	1,993		Stone	130	A
Southern Pacific Lines	U. S. Indestructible	Eagle Pass, Tex.	1916	23		Cinder	80	D
St. Louis–San Francisco	Clark-Applegate	Springfield, Mo.	1914	125	90	Cinder, Gravel, Chatts	85	C
Terminal R. R. Assn. of St. Louis	Miller	St. Louis, Mo.	1924	100	100	Cinder	100	A

*Linear Feet
†Changed from 85–lb. in 1930.
A —High speed, heavy service, passenger and freight.
B —High speed, exclusively passenger.
B1—Slow speed, exclusively passenger.
C —Heavy service, exclusively freight.
D—Main track, light service.
E—Yard track with heavy switching.
F—Yard track with light switching or storage usage.

TABLE A

CROSS TIES LAID IN REPLACEMENT - CLASS I STEAM ROADS UNITED STATES

Calendar year ended December 31, 1932

Road	Wooden ties untreated (U)		Wooden ties treated (T)		Ties other than wood(S) and second hand	Total ties applied	Miles of maintained tracks (item 24)	Estimated total cross ties in all maintained tracks (item 25)	Equated gross ton-miles A
	Number	Average cost	Number	Average cost					
1	2	3	4	5	6	7	8	9	10
NEW ENGLAND REGION:									
Bangor & Aroostook	171 793	$.79	-	-	-	171 793	845.50	2 433 209	1 335 420 592
Boston & Maine	27 836	1.12	197 430	$1.60	-	225 266	3 508.85	10 100 000	12 943 062 096
Canadian National Lines in N.E.	8 464	.83	6 108	1.85	-	14 572	255.48	785 708	433 581 496
Canadian Pacific Lines in Maine	593	.65	36 045	1.51	-	38 638	213.82	617 380	847 141 280
Canadian Pacific Lines in Vermont	Cr 260	.74	24 607	1.48	-	24 347	122.03	416 857	466 316 760
Central Vermont	1 581	.50	95 055	1.84	-	96 636	556.83	1 745 000	2 092 862 656
Maine Central	173 272	.98	79 040	1.54	-	252 312	1 370.83	4 158 000	3 006 607 536
New York Connecting	-	-	5 941	1.90	-	5 941	25.98	62 861	368 392 416
New York, New Haven & Hartford	1 259	.35	572 958	1.55	-	574 217	4 763.47	13 594 393	17 531 128 776
Rutland	-	-	99 430	1.43	-	99 430	525.66	1 578 000	1 700 416 496
GREAT LAKES REGION:									
Ann Arbor	-	-	74 716	1.48	-	74 716	417.52	1 252 860	1 188 945 392
Cambria & Indiana	14 370	1.16	-	-	-	14 370	61.18	166 600	126 663 000
Delaware & Hudson	12 439	1.16	173 627	2.39	(S) 14 076	200 142	1 463.28	4 509 220	7 623 403 520
Delaware, Lackawanna & Western	1 308	1.13	157 727	1.69	-	159 035	2 476.96	7 177 384	15 083 757 488
Detroit & Mackinac	18 176	.49	19 397	.98	* 129	37 702	297.05	891 141	224 079 448
Detroit & Toledo Shore Line	-	-	13 371	1.65	* 31	13 402	151.85	458 089	444 229 000
Erie (Inc. Chpo. & Erie)	3 940	.86	679 814	1.84	-	683 754	5 063.55	14 608 010	32 459 557 656
Grand Trunk Western	78 768	1.00	146 910	1.53	-	225 678	1 959.43	6 223 149	5 430 444 344
Lehigh & Hudson River	-	-	7 153	1.49	* 38	7 191	130.97	341 800	572 762 032
Lehigh & New England	322	.77	21 510	1.97	-	21 832	302.47	903 775	689 582 720
Lehigh Valley	-	-	152 977	1.83	-	152 977	3 381.13	9 188 271	13 935 625 992
Monongahela	18 626	1.43	1 641	2.29	-	20 267	249.83	719 349	727 256 568
Montour	1 513	1.43	6 118	1.81	-	7 631	80.21	224 588	217 492 000
New Jersey & New York	34	1.33	9 784	1.70	-	9 818	57.04	164 275	284 441 288
New York Central (Inc. U. & D)	8 303	1.00	1 201 931	1.67	*10 796	1 221 030	23 080.56	71 631 402	126 076 172 976
New York, Chicago & St. Louis	-	-	193 329	1.83	-	193 329	2 665.51	7 963 202	12 590 237 208
New York, Ontario & Western	704	.81	95 172	1.56	-	95 876	910.92	2 593 182	3 666 133 944
New York, Susquehanna & Western	-	-	26 724	1.46	-	26 724	237.71	684 806	560 307 544
Pere Marquette	1 894	.44	409 638	1.52	-	411 532	2 929.12	8 789 116	8 095 863 376
Pittsburgh & Lake Erie	-	-	4 889	1.98	-	4 889	956.74	2 866 494	3 093 803 024
Pittsburg & Shawmut	23 449	.74	-	-	(S) 48	23 497	129.13	358 844	192 687 152
Pittsburgh & West Virginia	17 910	1.29	-	-	-	17 910	202.69	587 833	408 753 160
Pittsburg, Shawmut & Northern	21 227	.81	11 813	1.70	(S) 10	33 050	235.70	685 708	278 648 640
Wabash	7 629	.92	442 133	1.54	-	449 762	3 345.00	10 403 749	16 492 773 664
CENTRAL EASTERN REGION:									
Akron, Canton & Youngstown	33 535	1.30	-	-	-	33 535	215.74	621 310	302 264 120
Atlantic City	657	.64	6 606	1.97	-	7 263	320.48	873 339	738 193 624
Baltimore & Ohio	6 007	1.15	518 649	1.67	-	524 656	11 051.24	31 435 645	49 586 214 344
Bessemer & Lake Erie	1 772	1.17	86 525	1.85	(S) 573	88 870	515.18	1 609 800	989 514 944
Central R.R. of New Jersey	-	-	109 696	1.82	-	109 696	1 520.62	4 280 677	7 260 293 424
Chicago & Eastern Illinois	49	1.26	153 929	1.45	-	153 978	1 546.37	4 795 139	5 054 208 376
Chicago & Illinois Midland	400	.50	17 450	1.04	-	17 850	159.75	492 672	574 671 496
Chicago, Indianapolis & Louisville	936	.63	59 896	1.29	* 1 409	60 241	887.62	2 734 663	3 146 920 000
Detroit, Toledo & Ironton	-	-	55 940	1.72	-	55 940	619.20	1 783 296	1 077 494 256
Elgin, Joliet & Eastern	-	-	87 367	1.43	* 5 467	92 834	909.16	2 803 138	1 726 952 000
Illinois Terminal	8 458	.75	52 930	1.31	*832	62 220	740.16	1 990 800	1 191 971 512
Long Island	20	.81	59 111	1.74	-	59 131	860.46	2 214 709	7 097 232 496
Missouri-Illinois	33 363	.41	261	1.14	-	33 624	243.59	763 800	174 152 600
Pennsylvania	6 777	1.28	1 098 801	1.66	-	1 105 578	22 784.54	64 000 000	130 215 954 464
Reading Co.	-	-	87 226	1.66	-	87 226	3 091.35	8 822 719	13 902 686 432
Staten Island Rapid Transit	-	-	5 528	2.44	-	5 528	102.70	295 776	372 046 752
Western Maryland	28 373	1.01	113 450	1.73	-	141 823	1 222.05	3 519 495	3 940 879 664
Wheeling & Lake Erie	5 810	.99	34 532	1.52	* 1 064	41 406	868.99	2 617 944	2 192 223 792
POCAHONTAS REGION:									
Chesapeake & Ohio	162	.37	444 420	1.22	-	444 582	5 304.09	16 326 935	40 307 002 312
Norfolk & Western	24	.50	499 875	1.20	-	499 899	4 387.76	13 602 056	25 618 210 000
Richmond, Fredericksburg & Potomac	113 189	.79	-	-	* 564	113 753	379.72	1 087 100	2 672 997 944
Virginian	51 299	.70	92 021	1.38	* 384	143 704	845.82	2 667 378	4 468 211 264
SOUTHERN REGION:									
Alabama Great Southern	8 157	.83	121 670	1.38	-	129 827	551.54	1 701 813	1 928 977 256
Atlanta & West Point	62	1.11	15 430	1.43	-	15 492	143.28	434 600	1 054 742 064
Western Ry. of Alabama	378	1.11	12 027	1.41	-	12 405	186.30	561 800	
Atlanta, Birmingham & Coast	79 915	.55	63 196	1.22	-	143 111	798.40	2 306 404	1 237 326 744
Atlantic Coast Line	521 844	.62	758 465	1.00	-	1 280 309	6 880.86	19 985 665	16 502 614 184
Central of Georgia	42 611	.65	234 227	.80	-	276 838	2 548.30	7 104 000	5 733 018 264
Charleston & Western Carolina	87 529	.96	-	-	-	87 529	427.74	1 248 429	560 179 792
Cincinnati, New Orleans & Tex. Pac.	4 967	.79	139 388	1.49	-	144 355	779.66	2 428 573	4 666 755 600
Clinchfield	98 866	.73	52 945	1.50	-	151 811	404.15	1 228 659	1 606 705 936
Columbus & Greenville	13 532	.67	33 476	1.24	-	47 008	205.29	650 359	236 203 712
Florida East Coast	139 231	.55	10	.65	-	139 241	1 500.02	4 306 054	2 823 747 448
Georgia R.R.	32 101	.96	45 566	1.53	-	77 667	435.69	1 332 163	1 184 118 144
Georgia & Florida	78 984	.56	-	-	-	78 984	508.22	1 372 194	293 930 672
Georgia, Southern & Florida	61 104	.86	11 316	1.36	-	72 420	473.63	1 488 646	1 045 355 864
Gulf & Ship Island	1 216	.20	9 438	.97	-	10 654	360.15	1 114 185	382 009 608
Gulf, Mobile & Northern	31 607	.41	65 548	.94	-	97 155	681.05	2 179 360	1 329 281 392
Illinois Central	12 528	1.21	b 622 603	1.08	-	635 131	7 990.75	24 356 773	40 616 912 568
Yazoo & Mississippi Valley	10 650	1.14	142 404	1.12	-	153 054	2 196.11	6 708 202	
Louisville & Nashville	61 233	1.16	686 508	1.66	-	747 741	7 283.86	20 747 320	27 849 709 432
Mississippi Central	1 261	.53	15 073	.96	-	16 334	170.17	536 091	167 606 288
Mobile & Ohio	350 920	.57	-	-	-	350 920	1 288.51	4 057 164	3 525 494 392
Nashville, Chattanooga & St. Louis	14 222	.42	367 306	1.19	-	381 528	1 570.62	4 663 745	4 932 763 608
New Orleans & Northeastern	506	1.01	62 992	1.24	-	63 498	285.44	881 528	1 014 978 472
New Orleans Great Northern	6 281	.46	31 034	.97	* 3 958	41 273	307.91	939 008	467 075 096
Norfolk Southern	178 205	.61	-	-	-	178 205	1 095.23	3 114 466	1 362 040 104
Northern Alabama	41 482	.76	-	-	-	41 482	127.83	404 175	152 545 400
Seaboard Air Line	779 027	.68	426 635	.88	-	1 205 662	5 618.96	17 451 100	14 096 874 672
Southern Ry.	1 765 786	.75	884 082	1.49	-	2 649 868	8 902.30	28 048 693	31 020 642 832
Tennessee Central	50 260	.56	35 192	1.94	-	85 452	347.61	1 085 251	603 997 112

TABLE A

CROSS TIES LAID IN REPLACEMENT - CLASS I STEAM ROAD UNITED STATES

Calendar year ended December 31, 1932

Road	Wooden ties untreated (U)		Wooden ties treated (T)		Ties other than wood(S) and second hand	Total ties applied	Miles of maintained tracks (item 24)	Estimated total cross ties in all maintained tracks (item 25)	Equated gross ton-miles a
	Number	Average cost	Number	Average cost					
1	2	3	4	5	6	7	8	9	10
NORTHWESTERN REGION:									
Chicago & North Western	66 237	$.67	1 287 773	$1.16	-	1 354 010	12 593.83	36 821 576	31 383 300 272
Chicago Great Western	200 616	.79	290 447	1.25	-	491 063	1 984.43	5 754 847	7 407 476 080
Chicago,Milwaukee,St.Paul & Pacific	433 771	.47	1 984 835	1.16	-	2 418 606	14 943.42	44 266 027	36 942 199 128
Chicago,St.Paul,Minneapolis & Omaha	65 574	.71	409 553	1.21	-	475 127	2 360.75	6 995 826	6 245 458 256
Duluth,Missabe & Northern	5 797	.63	7 090	1.81	-	12 887	1 210.79	3 624 689	509 944 944
Duluth,South Shore & Atlantic	105 890	.54	[illegible]	2.52	-	105 892	675.11	1 978 392	632 309 608
Duluth,Winnipeg & Pacific	53 226	.68	-	-	-	53 226	216.51	649 530	341 831 656
Great Northern	387 944	.50	1 043 546	1.17	*35 548	1 467 038	10 207.53	32 748 388	22 711 622 624
Green Bay & Western	77 923	.70	-	-	-	77 923	290.39	813 092	348 678 792
Lake Superior & Ishpeming	24 539	.73	-	-	-	24 539	234.39	703 170	62 747 544
Minneapolis & St.Louis	97 541	.81	84 824	1.43	-	182 365	1 814.46	5 462 527	3 036 411 544
Minneapolis,St.Paul & Sault Ste.Marie	328 159	.52	516 179	1.39	-	844 338	5 136.23	14 114 963	9 074 723 320
Northern Pacific	34 293	.43	894 059	1.23	(S) 25	928 377	9 177.36	26 644 318	18 420 493 464
Oregon-Washington R.R.& Nav.Co.	122	.36	144 519	.99	-	144 641	2 212.47	6 424 813	4 817 292 528
Spokane International	71 303	.49	-	-	-	71 303	194.09	548 369	168 599 800
Spokane,Portland & Seattle	57 500	.45	58 249	1.15	-	115 749	663.66	1 990 980	1 828 950 568
CENTRAL WESTERN REGION:									
Alton R.R.	333 521	1.00	1 516	1.67	*9 334	344 371	1 575.35	4 750 928	6 037 948 552
Atchison,Topeka & Santa Fe	10 069	.93	1 182 977	1.28	-	1 193 046	14 622.60	44 408 836)	54 161 234 488
Panhandle & Santa Fe	-	-	174 001	1.19	-	174 001	2 329.73	6 902 774)	
Chicago,Burlington & Quincy	-	-	1 365 422	1.25	*89 708	1 455 130	12 839.50	39 648 376	35 461 457 536
Chicago,Rock Island & Pacific	1 749	.50	374 889	1.12	-	376 638	9 882.69	29 763 893)	31 668 034 872
Chicago,Rock Island & Gulf	-	-	37 716	1.68	*2 062	39 778	853.74	2 503 529)	
Colorado & Southern	57 720	.40	70 278	1.27	*14 267	142 265	1 142.97	3 458 776	1 959 677 528
Denver & Rio Grande Western	21 662	.88	428 028	1.10	a 180 377	630 067	3 464.07	10 775 680	7 541 414 232
Denver & Salt Lake	20 584	.81	19 563	1.24	-	40 147	326.57	979 620	473 649 616
Fort Worth & Denver City	-	-	65 485	1.31	-	65 485	969.51	2 914 280	2 171 185 112
Los Angeles & Salt Lake	-	-	170 579	1.62	-	170 579	1 517.21	4 257 662	6 628 131 328
Nevada Northern	25 502	.77	-	-	-	25 502	190.83	547 695	81 436 848
Northwestern Pacific	58 007	.62	-	-	-	58 007	547.83	1 617 518	880 760 280
Oregon Short Line	285	.80	195 903	1.32	-	196 188	3 325.16	9 227 760	8 077 282 784
St.Joseph & Grand Island	23 453	1.23	43	2.05	-	23 496	338.31	1 001 742	902 145 936
San Diego & Arizona	14 227	.96	-	-	*561	14 788	169.14	498 922	80 576 024
Southern Pacific-Pacific Lines	267 228	.82	983 510	1.16	-	1 250 738	12 892.68	37 857 895	47 147 799 232
Toledo,Peoria & Western	42 569	.88	2	1.43	*1 378	43 949	274.58	869 869	447 187 624
Union Pacific	179	.99	509 865	1.39	-	510 044	6 013.00	16 968 900	34 878 923 912
Utah Ry.	6 309	.73	3 459	1.97	-	9 768	89.15	231 790	276 611 000
Western Pacific	291 752	.64	-	-	-	291 752	1 468.60	4 306 000	5 308 022 664
SOUTHWESTERN REGION:									
Burlington-Rock Island	-	-	6 315	1.00	-	6 315	281.57	846 445	395 039 456
Fort Smith & Western	59 751	.43	-	-	-	59 751	235.12	734 500	305 172 408
Fort Worth & Rio Grande	2 610	.74	35 589	1.29	-	38 199	245.37	777 332	230 900 528
Gulf Coast Lines:									
Beaumont,Sour Lake & Western	-	-	8 245	1.14	*297	8 542	141.55	421 200)	3 212 365 888
New Orleans,Texas & Mexico	-	-	20 975	1.13	-	20 975	224.93	688 200)	
St.Louis,Brownsville & Mexico	-	-	21 183	1.04	*236	21 419	749.04	2 270 200)	
Gulf,Colorado & Santa Fe	2 802	.34	147 562	1.23	-	150 364	2 555.42	8 274 450	5 823 996 632
International-Great Northern	-	-	141 303	.98	-	141 303	1 523.40	4 559 600	4 634 128 456
Kansas City Southern	80	.55	168 950	1.06	-	169 030	1 115.84	3 501 930)	3 611 202 296
Texarkana & Fort Smith	-	-	15 325	1.08	-	15 325	169.63	475 658)	
Kansas,Oklahoma & Gulf	987	.36	32 997	1.03	-	33 984	370.02	1 178 066	636 122 376
Louisiana & Arkansas	72 427	.63	62 723	.97	-	135 150	734.28	2 318 191	1 195 032 440
Louisiana,Arkansas & Texas	26 804	.41	29 383	.99	-	56 187	232.00	742 600	241 565 816
Midland Valley	654	.41	31 126	1.08	-	31 780	418.95	1 345 976	379 719 648
Missouri & North Arkansas	65 254	.43	-	-	-	65 254	365.64	1 139 793	366 963 400
Missouri-Kansas-Texas Lines:									
Missouri-Kansas-Texas	297 232	.78	1 174	1.31	-	298 406	2 318.83	7 311 663)	12 564 892 880
Missouri-Kansas-Texas of Texas	182 969	.76	223	1.31	-	183 192	1 702.69	5 401 660)	
Missouri Pacific	137 509	.75	765 064	1.08	-	902 573	9 401.99	29 142 726	34 057 221 832
Oklahoma City-Ada-Atoka	13 088	.57	1 781	1.07	-	14 869	152.73	480 260	94 104 184
St.Louis-San Francisco	96 275	.45	1 065 457	1.04	-	1 161 732	6 953.53	21 592 391	16 621 909 144
St.Louis,San Francisco & Texas	7 738	.55	33 819	1.31	-	41 557	254.03	804 767	315 095 744
St.Louis Southwestern Lines:									
St.Louis Southwestern	610	.26	83 518	1.22	*2 265	86 393	1 120.97	3 551 219)	5 042 442 336
St.Louis Southwestern of Texas	-	-	79 053	1.19	*5 348	84 401	971.42	3 077 459)	
San Antonio,Uvalde & Gulf	-	-	47 994	1.20	*217	48 211	364.73	1 051 200	420 389 432
Texas & New Orleans	88 772	1.06	493 151	1.15	-	581 923	5 899.38	15 939 327	13 429 636 032
Texas & Pacific	126	.59	136 468	1.07	-	136 594	2 545.63	7 501 502	9 481 326 336
Texas Mexican	-	-	31 276	1.05	*310	31 586	205.97	593 202	158 839 200
Wichita Falls & Southern	-	-	34 818	.99	-	34 818	198.18	653 994	109 033 016

* All second hand ties.
a Maleheider formula.
b Includes second hand ties.
n Indicates narrow gauge ties.

NOTE: Compiled from Annual Reports of Class I Steam Roads to the Interstate Commerce Commission.

TABLE B

WOODEN CROSS TIES LAID IN REPLACEMENT (TREATND & UNTREATND) ON LEADING RAILROADS IN THE UNITED STATES

Calendar year ended December 31, 1932

NOTE: All figures are exclusive of bridge & switch ties

Road	Miles of maintained track occupied by wooden cross ties (Col.8-Table A)	Average number of wooden cross ties per mile of maintained track	Total number of wooden cross ties renewed 1932	Average number of wooden cross ties renewed per mile of maintained track	Weighted average cost per wooden cross tie	Average cost of wooden cross tie renewals per mile of maintained track	Average percentage of wooden cross tie renewals	Equated gross ton-miles per mile of maintained track	Cost of wooden cross tie renewals per thousand equated gross ton-miles
1	2	3	4	5	6	7	8	9	10
NEW ENGLAND REGION:									
Bangor & Aroostook	845.50	2 878	171 793	203	$.79	$160	7.1	1 579 445	$.101
Boston & Maine	3 508.85	2 878	225 266	64	1.54	99	2.2	3 688 691	.027
Canadian Nat.Lines in New Eng.	255.48	3 075	14 572	57	1.26	72	1.9	1 697 125	.042
Canadian Pacific (lines in Me.)	213.82	2 867	38 638	181	1.50	270	6.3	3 961 937	.068
Canadian Pacific (lines in Vt.)	122.03	3 415	24 347	200	1.49	297	5.8	3 821 329	.078
Central Vermont	556.83	3 134	96 636	174	1.82	315	5.5	3 686 696	.086
Maine Central	1 370.83	3 033	252 312	184	1.15	212	6.1	2 193 275	.097
New York Connecting	25.98	3 189	5 941	229	1.90	434	7.2	10 330 732	.042
New York,New Haven & Hartford	4 763.47	2 854	574 217	121	1.55	187	4.2	3 680 327	.051
Rutland	525.66	3 002	99 430	189	1.43	270	6.3	3 234 822	.084
GREAT LAKES REGION:									
Ann Arbor	417.52	3 001	74 716	179	1.48	264	6.0	2 847 637	.093
Cambria & Indiana	61.18	2 723	14 370	235	1.16	273	8.6	2 070 333	.132
Delaware & Hudson	1 483.28	3 040	186 066	125	2.30	289	4.1	5 139 558	.056
Delaware,Lackawanna & Western	2 476.96	2 898	159 035	64	1.69	108	2.2	6 089 625	.018
Detroit & Mackinac	297.05	3 000	17 571	126	.76	95	4.2	754 349	.125
Detroit & Toledo Shore Line	151.85	3 017	13 371	88	1.65	145	2.9	2 925 446	.050
Erie (Inc.Chgo.& Erie)	5 063.55	2 885	683 754	135	1.83	248	4.7	6 410 435	.039
Grand Trunk Western	1 959.43	3 176	225 678	115	1.34	155	3.6	2 771 441	.056
Lehigh & Hudson River	130.97	2 610	7 153	55	1.49	81	2.1	4 373 231	.019
Lehigh & New England	302.47	2 988	21 832	72	1.95	141	2.4	2 279 838	.062
Lehigh Valley	3 381.13	2 718	152 977	45	1.83	83	1.7	4 121 588	.020
Monongahela	249.83	2 879	20 267	81	1.50	121	2.8	2 911 006	.042
Montour	80.21	2 800	7 631	95	1.74	165	3.4	2 711 532	.061
New Jersey & New York	57.04	2 880	9 818	172	1.70	293	6.0	4 986 699	.059
New York Central (Inc.U.& D.)	23 030.56	3 104	1 210 234	52	1.66	87	1.7	5 462 440	.016
New York,Chicago & St.Louis	2 665.51	2 987	195 329	73	1.83	133	2.4	4 723 388	.028
New York,Ontario & Western	910.92	2 847	95 876	105	1.55	163	3.7	4 024 650	.041
New York,Susquehanna & Western	237.71	2 381	26 724	112	1.46	164	3.9	2 357 105	.070
Pere Marquette	2 929.12	3 001	411 532	140	1.52	213	4.7	2 763 923	.077
Pittsburgh & Lake Erie	956.74	2 996	4 889	5	1.98	10	0.2	3 233 693	.003
Pittsburg & Shawmut	129.13	2 779	23 449	182	.74	134	6.5	1 492 195	.090
Pittsburgh & West Virginia	202.69	2 900	17 910	88	1.29	114	3.0	2 016 642	.057
Pittsburg,Shawmut & Northern	235.70	2 909	33 040	140	1.13	159	4.8	1 182 217	.134
Wabash	3 345.00	3 110	449 762	134	1.53	205	4.3	4 930 575	.042
CENTRAL EASTERN REGION:									
Akron,Canton & Youngstown	215.74	2 880	33 535	155	1.30	202	5.4	1 401 057	.144
Atlantic City	320.48	2 725	7 263	23	1.85	42	0.8	2 303 400	.018
Baltimore & Ohio	11 051.24	2 845	524 656	47	1.67	79	1.7	4 486 937	.018
Bessemer & Lake Erie	515.18	3 125	88 297	171	1.84	315	5.5	1 920 717	.164
Central R.R.of New Jersey	1 520.62	2 815	109 696	72	1.82	131	2.6	4 774 561	.027
Chicago & Eastern Illinois	1 546.37	3 101	155 978	100	1.45	144	3.2	3 868 434	.037
Chicago & Illinois Midland	159.75	3 084	17 850	112	1.03	115	3.6	3 597 318	.032
Chicago,Indpls.& Louisville	887.62	3 081	58 832	66	1.27	84	2.2	3 545 346	.024
Detroit,Toledo & Ironton	619.20	2 880	55 940	90	1.72	155	3.1	1 740 139	.089
Elgin,Joliet & Eastern	909.16	3 083	87 367	96	1.43	137	3.1	1 899 503	.072
Illinois Terminal	740.16	2 990	61 388	83	1.24	103	3.1	1 610 424	.064
Long Island	860.46	2 574	59 131	69	1.74	120	2.7	8 248 184	.015
Missouri-Illinois	243.59	3 136	33 624	138	.42	58	4.4	714 942	.081
Pennsylvania	22 784.54	2 809	1 105 578	48	1.66	81	1.7	5 715 101	.014
Reading Co.	3 091.35	2 854	87 226	28	1.66	47	1.0	4 497 286	.010
Staten Island Rapid Transit	102.70	2 880	5 528	54	2.44	131	1.9	3 622 656	.036
Western Maryland	1 222.05	2 880	141 823	116	1.59	185	4.0	3 224 810	.057
Wheeling & Lake Erie	868.99	3 013	40 342	46	1.44	67	1.5	2 522 726	.027
POCAHONTAS REGION:									
Chesapeake & Ohio	5 304.09	3 078	444 582	84	1.22	102	2.7	7 599 230	.013
Norfolk & Western	4 387.76	3 100	499 899	114	1.20	136	3.7	5 838 562	.023
Richmond,Fred.& Potomac	379.72	2 863	113 189	298	.79	236	10.4	7 039 392	.034
Virginian	845.82	3 154	143 320	169	1.14	193	5.4	5 282 698	.036
SOUTHERN REGION:									
Alabama Great Southern	551.54	3 086	129 827	235	1.35	317	7.6	3 497 439	.091
Atlanta & West Point	143.28	3 033	15 492	108	1.42	154	3.6)	3 200 261	.037
Western Ry.of Ala.	186.30	3 016	12 405	67	1.40	93	2.2)		
Atlanta,Birmingham & Coast	798.40	2 889	143 111	179	.84	151	6.2	1 549 758	.098
Atlantic Coast Line	6 880.86	2 905	1 280 309	186	.85	157	6.4	2 398 336	.066
Central of Georgia	2 548.30	2 788	276 838	109	.78	84	3.9	2 249 742	.037
Charleston & Western Carolina	427.74	2 919	87 529	205	.96	197	7.0	1 309 627	.151
Cincinnati,New Orleans & Tex.Pac.	779.66	3 115	144 355	185	1.46	271	5.9	5 985 629	.045
Clinchfield	404.15	3 040	151 811	376	1.00	375	12.4	3 972 539	.094
Columbus & Greenville	205.29	3 168	47 008	229	1.08	247	7.2	1 150 586	.215
Florida East Coast	1 500.02	2 871	139 241	93	.55	51	3.2	1 882 473	.027
Georgia R.R.	435.69	3 058	77 667	178	1.29	230	5.8	2 717 800	.085
Georgia & Florida	508.22	2 700	78 984	155	.56	87	5.8	578 353	.150
Georgia,Southern & Florida	473.63	3 143	72 420	153	.94	144	4.9	2 207 135	.065
Gulf & Ship Island	350.15	3 094	10 654	30	.88	26	1.0	1 060 696	.025
Gulf,Mobile & Northern	681.05	3 200	97 155	143	.77	110	4.5	1 951 812	.056
Illinois Central	7 990.75	3 048	635 131	79	1.09	86	2.6)	3 987 187	.021
Yazoo & Miss.Valley	2 196.11	3 055	153 054	70	1.12	78	2.3)		
Louisville & Nashville	7 283.86	2 848	747 741	103	1.62	167	3.6	3 823 482	.044
Mississippi Central	170.17	3 150	16 334	96	.93	89	3.0	984 934	.090
Mobile & Ohio	1 238.51	3 149	350 920	272	.57	154	8.6	2 736 102	.056
Nashville,Chattanooga & St.Louis	1 570.62	2 969	381 528	243	1.16	282	8.2	3 140 647	.090
New Orleans & Northeastern	285.44	3 089	63 498	222	1.24	276	7.2	3 555 838	.077
New Orleans Great Northern	307.91	3 049	37 315	121	.88	107	4.0	1 516 921	.070
Norfolk Southern	1 095.23	2 844	178 205	163	.61	99	5.7	1 243 611	.079
Northern Alabama	127.83	3 162	41 482	325	.76	248	10.3	1 193 346	.208
Seaboard Air Line	5 618.96	3 106	1 205 662	215	.75	161	6.9	2 508 805	.064
Southern Ry.	8 902.30	3 151	2 649 868	298	1.00	296	9.4	3 484 565	.085
Tennessee Central	347.61	3 122	85 452	246	1.13	277	7.9	1 737 571	.159

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TABLE B

WOODEN CROSS TIES LAID IN REPLACEMENT (TREATED & UNTREATED) ON LEADING RAILROADS IN THE UNITED STATES

Calendar year ended December 31, 1932

NOTE: All figures are exclusive of bridge & switch ties

Road	Miles of maintained track occupied by wooden cross ties (Col.8-Table A)	Average number of wooden cross ties per mile of maintained track	Total number of wooden cross ties renewed 1932	Average number of wooden cross ties renewed per mile of maintained track	Weighted average cost per wooden cross tie	Average cost of wooden cross tie renewals per mile of maintained track	Average percentage of wooden cross tie renewals	Equated gross ton-miles per mile of maintained track	Cost of wooden cross tie renewals per thousand equated gross ton-miles
1	2	3	4	5	6	7	8	9	10
NORTHWESTERN REGION:									
Chicago & North Western	12 593.83	2 924	1 354 010	108	$1.14	$123	3.7	2 491 958	$.049
Chicago Great Western	1 984.43	2 900	491 063	247	1.07	264	8.5	3 732 798	.071
Chicago, Milwaukee, St.Paul & Pacific	14 943.42	2 962	2 418 606	162	1.03	167	5.5	2 472 138	.068
Chicago, St.Paul, Minpls.& Omaha	2 360.75	2 963	475 127	201	1.14	229	6.8	2 645 540	.087
Duluth, Missabe & Northern	1 210.79	2 994	12 887	11	1.28	14	0.4	421 167	.032
Duluth, South Shore & Atlantic	575.11	2 930	105 892	157	.54	84	5.4	936 602	.090
Duluth, Winnipeg & Pacific	216.51	3 000	53 226	246	.68	167	8.2	1 578 826	.106
Great Northern	10 207.53	3 208	1 431 490	140	.98	138	4.4	2 224 987	.062
Green Bay & Western	290.39	2 800	77 923	268	.70	189	9.6	1 200 726	.157
Lake Superior & Ishpeming	234.39	3 000	24 539	105	.73	76	3.5	267 706	.284
Minneapolis & St.Louis	1 814.46	3 011	182 365	101	1.10	111	3.3	1 673 452	.066
Minneapolis, St.Paul & S.S.Marie	5 136.23	2 748	844 338	164	1.05	173	6.0	1 766 806	.098
Northern Pacific	9 177.36	2 903	928 352	101	1.20	122	3.5	2 007 167	.061
Oregon-Washington R.R.& Nav.Co.	2 212.47	2 904	144 641	65	.99	65	2.3	2 177 337	.030
Spokane International	194.09	2 825	71 303	367	.49	182	13.0	868 668	.209
Spokane, Portland & Seattle	663.66	3 000	115 749	174	.80	140	5.8	2 755 855	.051
CENTRAL WESTERN REGION:									
Alton R.R.	1 575.35	3 016	335 037	213	1.00	212	7.1	3 832 766	.055
Atchison, Topeka & Santa Fe	14 622.60	3 037	1 193 046	82	1.28	104	2.7)	3 194 914	.032
Panhandle & Santa Fe	2 329.73	2 963	174 001	75	1.19	89	2.5)		
Chicago, Burlington & Quincy	12 839.50	3 088	1 365 422	106	1.25	133	3.4	2 761 903	.048
Chicago, Rock Island & Pacific	9 882.69	3 012	376 638	38	1.11	42	1.3)	2 949 587	.015
Chicago, Rock Island & Gulf	853.74	2 932	37 716	44	1.68	74	1.5)		
Colorado & Southern	1 142.97	3 026	127 998	112	.88	98	3.7	1 714 549	.057
Denver & Rio Grande Western	3 464.07	3 111	449 690	130	1.09	141	4.2	2 177 039	.065
Denver & Salt Lake	326.57	3 000	40 147	123	1.02	125	4.1	1 450 377	.086
Fort Worth & Denver City	969.51	3 006	65 485	68	1.31	88	2.2	2 239 466	.039
Los Angeles & Salt Lake	1 517.21	2 886	170 579	112	1.62	182	4.0	4 368 631	.042
Nevada Northern	190.83	2 870	25 502	134	.77	103	4.7	426 751	.242
Northwestern Pacific	547.83	2 953	58 007	106	.62	66	3.6	1 607 726	.041
Oregon Short Line	3 325.16	2 775	196 188	59	1.31	78	2.1	2 429 141	.032
St.Joseph & Grand Island	338.31	2 961	23 496	69	1.23	86	2.3	2 903 095	.030
San Diego & Arizona	169.14	2 950	14 227	84	.96	80	2.9	476 387	.169
Southern Pacific Co.- Pacific Lines	12 892.68	2 936	1 250 738	97	1.09	105	3.3	3 656 943	.029
Toledo, Peoria & Western	274.58	2 168	42 571	155	.88	137	4.9	1 628 624	.084
Union Pacific	6 013.00	2 822	510 044	85	1.39	118	3.0	5 800 586	.020
Utah Ry.	89.15	2 600	9 768	110	1.17	128	4.2	3 102 759	.041
Western Pacific	1 468.82	2 932	291 752	199	.64	127	6.8	3 654 650	.035
SOUTHWESTERN REGION:									
Burlington-Rock Island	281.57	3 006	6 315	22	1.00	22	0.7	1 402 988	.016
Fort Smith & Western	235.12	3 124	59 751	254	.43	110	8.1	1 297 944	.085
Fort Worth & Rio Grande	245.37	3 168	38 199	156	1.25	195	4.9	941 030	.207
Gulf Coast Lines:									
Beaumont, Sour Lake & Western	141.55	2 976	8 245	58	1.14	66	2.0)	2 879 703	.017
New Orleans, Texas & Mexico	224.93	3 060	20 975	93	1.13	105	3.0)		
St.Louis, Brownsville & Mexico	749.04	3 031	21 183	28	1.04	29	0.9)		
Gulf, Colorado & Santa Fe	2 555.42	3 238	150 364	59	1.22	72	1.8	2 279 076	.031
International-Great Northern	1 523.40	2 993	141 303	93	.98	91	3.1	3 041 964	.030
Kansas City Southern	1 115.84	3 138	169 030	151	1.06	160	4.8)	2 809 247	.054
Texarkana & Fort Smith	169.63	2 804	15 325	90	1.08	98	3.2)		
Kansas, Oklahoma & Gulf	370.02	3 184	33 984	92	1.01	93	2.9	1 719 157	.054
Louisiana & Arkansas	734.28	3 157	135 150	184	.79	146	5.8	1 627 489	.089
Louisiana, Arkansas & Texas	232.00	3 201	56 187	242	.71	173	7.6	1 041 232	.166
Midland Valley	418.95	3 213	31 780	76	1.06	80	2.4	906 360	.088
Missouri & North Arkansas	365.64	3 117	65 254	178	.43	77	5.7	1 003 619	.076
Missouri-Kansas-Texas Lines:									
Missouri-Kansas-Texas	2 318.83	3 153	298 406	129	.78	101	4.1)	3 124 414	.030
Missouri-Kansas-Texas of Tex.	1 702.69	3 172	183 192	108	.76	82	3.4)		
Missouri Pacific	9 401.99	3 100	902 573	96	1.03	99	3.1	3 622 342	.027
Oklahoma City-Ada-Atoka	152.73	3 145	14 869	97	.63	61	3.1	616 147	.100
St.Louis-San Francisco	6 953.53	3 105	1 161 732	167	.99	166	5.4	2 390 427	.069
St.Louis, San Francisco & Texas	254.03	3 168	41 557	164	1.17	191	5.2	1 240 388	.154
St.Louis Southwestern Lines:									
St.Louis Southwestern	1 120.97	3 168	84 128	75	1.22	91	2.4)	2 409 896	.039
St.Louis Southwestern of Tex.	971.42	3 168	79 053	81	1.19	97	2.6)		
San Antonio, Uvalde & Gulf	364.73	2 882	47 994	132	1.20	158	4.6	1 152 604	.137
Texas & New Orleans	5 899.38	2 702	581 923	99	1.13	112	3.7	2 276 449	.049
Texas & Pacific	2 545.63	2 947	136 594	54	1.06	57	1.8	3 724 590	.015
Texas Mexican	205.97	2 880	31 276	152	1.05	159	5.3	771 176	.206
Wichita Falls & Southern	198.18	3 300	34 818	176	.99	174	5.3	550 172	.316

Col.3 derived by dividing Col.9 Table A by Col.8 of same table.
Col.4 is total of columns 2 and 4 of Table A.
Col.5 derived by dividing the totals of columns 2 and 4 of Table A, by Col.8 of same table.
Col.6 is weighted average of costs shown in columns 3 and 5 of Table A.
NOTE: Compiled from Annual Reports of Class I Steam Roads to the Interstate Commerce Commission.

TABLE C

AVERAGE NUMBER AND AVERAGE COST OF WOODEN CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF WOODEN CROSS TIE RENEWALS TO TOTAL WOODEN CROSS TIES IN MAINTAINED TRACK

Class I roads in the United States, by years, and for the average of the five years 1928 to 1932 inclusive

Note: All figures are exclusive of bridge and switch ties

Road	Average number of wooden cross tie renewals per mile of maintained track						Average cost of wooden cross tie renewals per mile of maintained track						Average percentage of wooden cross tie renewals					
	1928	1929	1930	1931	1932	5 year average	1928	1929	1930	1931	1932	5 year average	1928	1929	1930	1931	1932	5 year average
NEW ENGLAND REGION:																		
Bangor & Aroostook	230	255	253	236	203	235	$179	$212	$207	$183	$160	$189	8.3	8.8	8.8	8.2	7.1	8.2
Boston & Maine	277	260	236	164	64	203	468	426	385	271	99	335	9.9	9.1	8.7	5.4	2.2	7.1
Canadian National Lines in N.E.	199	235	160	87	57	146	368	383	251	129	72	238	6.3	7.4	5.0	2.8	1.9	4.6
Canadian Pacific Lines in Maine	330	311	320	262	181	281	426	395	397	362	270	370	11.4	10.8	11.1	9.1	6.3	9.7
Canadian Pacific Lines in Vermont	518	326	313	254	200	322	637	385	413	362	297	419	16.2	10.6	10.0	7.5	5.8	9.9
Central Vermont	312	249	244	237	174	243	549	453	427	421	315	434	9.7	7.8	7.6	7.5	5.5	7.7
Maine Central	229	204	244	222	184	217	254	224	273	257	212	244	7.5	6.7	8.0	7.3	6.1	7.2
New York Connecting	73	238	194	293	229	205	153	488	382	580	434	408	2.3	7.4	6.1	9.3	7.2	6.4
New York,New Haven & Hartford	328	267	253	165	121	224	558	486	412	277	187	380	9.8	8.6	8.2	5.8	4.2	7.3
Rutland	282	270	224	210	189	235	485	459	365	337	270	384	9.4	9.3	7.5	7.0	6.3	7.9
GREAT LAKES REGION:																		
Ann Arbor	242	202	148	114	179	177	397	339	226	175	264	280	8.1	6.7	4.9	3.8	6.0	5.9
Cambria & Indiana	a	a	a	a	235	235	a	a	a	a	273	273	a	a	a	a	8.6	8.6
Delaware & Hudson	127	201	172	111	125	147	305	519	432	266	289	362	4.5	6.7	5.7	3.6	4.1	4.9
Delaware,Lackawanna & Western	98	84	80	76	64	81	184	159	151	141	108	149	3.4	2.9	2.8	2.6	2.2	2.8
Detroit & Mackinac	232	164	202	97	126	167	295	162	194	107	95	176	7.5	5.5	6.7	3.2	4.2	5.5
Detroit & Toledo Shore Line	163	132	112	84	88	115	319	269	235	177	145	228	5.2	4.2	3.6	2.7	2.9	3.7
Erie (Inc.Chgo.& Erie)	210	221	199	173	135	188	443	480	422	341	248	386	8.1	8.2	7.0	6.1	4.7	6.8
Grand Trunk Western (See note)	347	303	191	156	115	215	486	400	252	210	155	289	10.4	9.4	5.9	4.8	3.6	6.6
Lehigh & Hudson River	51	49	66	54	55	55	83	80	127	100	81	94	1.9	1.9	2.5	2.1	2.1	2.1
Lehigh & New England	118	132	121	107	72	110	238	257	243	207	141	218	4.2	4.5	4.1	3.6	2.4	3.7
Lehigh Valley	65	74	64	53	45	60	131	147	118	97	83	115	2.2	2.5	2.2	1.8	1.7	2.1
Monongahela	277	202	215	145	81	184	493	347	368	228	121	311	9.1	6.9	7.6	5.0	2.8	6.3
Montour	307	306	259	163	95	224	706	655	552	302	165	471	10.9	10.8	9.2	5.8	3.4	8.0
New Jersey & New York	195	124	167	145	172	160	390	258	319	260	293	304	5.8	4.8	5.8	5.0	6.0	5.5
New York Central R.R.Co.(See note)	138	129	111	91	52	104	265	248	207	163	87	194	4.9	4.6	3.8	3.1	1.7	3.6
New York,Chicago & St.Louis	169	169	135	70	73	122	331	330	254	132	133	234	5.5	5.2	4.2	2.3	2.4	3.9
New York,Ontario & Western	174	134	119	116	105	130	331	[illegible]	206	196	163	228	6.1	4.7	4.2	4.1	3.7	4.6
New York,Susquehanna & Western	218	205	174	125	112	167	401	404	322	204	164	299	8.3	8.0	6.0	4.3	3.9	6.0
Pere Marquette	227	213	168	191	140	187	329	302	294	319	213	292	7.6	7.1	6.4	6.3	4.7	6.4
Pittsburgh & Lake Erie	91	73	62	4	5	48	220	165	151	7	10	114	3.6	2.5	2.1	0.1	0.2	1.7
Pittsburg & Shawmut	319	322	158	159	182	228	357	361	188	136	134	235	k	11.6	5.7	5.7	6.5	8.4
Pittsburgh & West Virginia	93	182	108	117	88	116	161	297	176	151	114	174	3.2	6.3	3.7	4.0	3.0	4.0
Pitsburg,Shawmut & Northern	264	243	185	165	140	200	312	401	333	210	159	284	9.4	8.7	6.4	5.7	4.8	7.0
Wabash	238	221	177	119	134	178	374	347	253	145	205	265	7.6	7.0	5.6	3.8	4.3	5.7
CENTRAL EASTERN REGION:																		
Akron,Canton & Youngstown	375	363	250	115	155	251	536	581	445	212	202	394	11.8	12.6	8.7	4.0	5.4	8.5
Atlantic City	98	104	109	114	23	89	221	212	230	230	42	186	3.4	3.6	3.9	4.0	0.8	3.1
Baltimore & Ohio (See note)	165	153	123	51	47	110	292	259	205	82	79	186	6.0	5.6	4.4	1.8	1.7	3.9
Bessemer & Lake Erie	224	227	231	238	171	218	455	472	508	465	315	444	7.1	7.2	7.3	7.6	5.5	6.9
Central R.R.of New Jersey	85	79	83	82	72	80	176	164	156	151	131	155	3.2	2.8	2.9	2.9	2.6	2.9
Chicago & Eastern Illinois	132	119	101	98	100	110	211	181	152	145	144	167	4.0	4.0	3.2	3.2	3.2	3.5
Chicago & Illinois Midland	268	223	126	105	112	166	351	343	202	148	115	239	9.4	7.8	4.2	3.5	3.6	5.6
Chicago,Indianapolis & Louisville	130	132	106	99	66	117	177	180	207	128	84	155	4.2	4.3	5.1	3.8	2.8	3.8
Detroit,Toledo & Ironton	113	164	149	71	90	118	211	325	244	117	155	212	4.0	5.7	5.2	2.5	3.1	4.1
Elgin,Joliet & Eastern	280	269	226	165	96	206	395	385	353	248	137	302	9.1	8.7	7.3	5.3	3.1	6.7
Illinois Terminal	114	77	94	84	83	90	164	115	130	105	100	122	3.8	2.9	3.5	3.1	3.1	3.3
Long Island	224	193	129	91	69	141	450	392	241	167	120	274	8.0	6.9	4.6	3.2	2.7	5.1
Missouri-Illinois	c	260	197	221	138	204	c	187	201	153	58	150	c	9.0	6.4	7.1	4.4	6.7
Pennsylvania R.R. (See note)	167	159	124	75	48	115	331	312	227	138	81	218	6.1	5.8	4.4	2.7	1.7	4.1
Reading Co. (See note)	156	148	137	105	28	115	309	289	247	188	47	216	5.4	5.2	4.8	3.8	1.0	4.0
Staten Island Rapid Transit	113	76	73	62	54	76	251	142	147	128	131	160	4.1	2.8	2.6	2.3	1.9	2.7
Western Maryland	378	256	206	187	116	227	567	389	274	238	185	328	13.1	8.9	7.1	6.5	4.0	7.9
Wheeling & Lake Erie	307	267	171	133	46	186	522	446	258	203	67	300	10.2	8.9	5.7	4.4	1.5	6.2
POCAHONTAS REGION:																		
Chesapeake & Ohio (See note)	251	211	173	127	84	168	351	283	239	157	102	225	8.4	7.1	5.6	4.1	2.7	5.5
Norfolk & Western	223	203	176	164	114	176	357	311	246	214	136	253	7.0	6.6	5.7	5.3	3.7	5.7
Richmond,Fredericksburg & Potomac	326	424	401	295	298	349	378	471	457	286	236	366	11.4	14.8	14.0	10.3	10.4	12.2
Virginian	359	355	342	234	169	291	402	387	373	249	193	319	11.4	11.1	10.9	7.4	5.4	9.2
SOUTHERN REGION:																		
Alabama Great Southern	456	409	342	343	235	357	570	515	469	491	317	472	14.8	13.4	11.1	11.1	7.6	11.6
Atlanta & West Point	207	190	198	160	108	173	282	255	255	228	154	235	6.5	7.2	7.5	6.1	3.6	6.1
Western Ry.of Alabama	356	231	268	171	57	216	506	305	346	244	93	296	11.4	7.7	8.9	6.5	2.2	7.3
Atlanta,Birmingham & Coast	332	303	243	222	179	256	372	324	277	253	151	275	11.5	10.4	8.4	7.7	6.2	8.9
Atlantic Coast Line	224	234	218	210	186	214	253	262	238	214	157	224	7.7	8.1	7.5	7.2	6.4	7.4
Central of Georgia	191	204	144	143	109	158	193	190	131	120	84	144	6.9	7.3	5.2	5.1	3.9	5.7
Charleston & Western Carolina	300	310	295	237	205	266	318	372	327	256	197	295	10.3	10.7	9.9	8.6	7.0	9.3
Cincinnati,New Orleans & Texas Pacific	441	394	300	281	185	317	657	595	447	432	271	475	14.3	12.8	9.3	9.1	5.9	10.2
Clinchfield	407	476	477	399	376	427	387	471	425	394	375	410	13.4	15.6	15.7	13.1	12.4	14.0
Columbus & Greenville	540	447	415	152	229	356	702	554	519	171	247	438	17.0	14.1	13.1	4.8	7.2	11.2
Florida East Coast	95	62	36	34	93	64	152	106	40	32	51	77	3.6	2.2	1.2	1.2	3.2	2.3
Georgia R.R.	226	286	250	240	178	236	307	395	335	326	230	319	7.3	9.6	8.3	8.1	5.8	7.8
Georgia & Florida	191	182	216	256	155	200	111	137	157	163	87	131	7.5	6.8	8.0	9.5	5.8	7.5
Georgia,Southern & Florida	346	367	247	256	153	274	401	396	259	263	144	293	10.5	11.7	7.9	8.2	4.9	8.7
Gulf & Ship Island	248	359	320	288	30	248	315	445	352	292	26	285	8.0	11.5	10.4	9.3	1.0	8.0
Gulf,Mobile & Northern	199	210	213	147	143	183	207	214	215	153	110	181	6.6	7.0	6.7	4.6	4.5	5.9
Illinois Central	179	188	161	166	79	155	222	214	187	190	[illegible]	180	5.6	6.1	5.3	5.4	2.6	5.1
Yazoo & Mississippi Valley	278	298	237	236	70	224	367	361	294	285	78	278	9.1	9.7	7.6	7.7	2.3	7.3
Louisville & Nashville (See note)	240	235	200	168	103	190	410	376	314	273	167	309	8.3	8.2	7.2	5.8	3.6	6.6
Mississippi Central	157	197	204	167	96	164	177	225	237	171	89	186	5.0	6.3	6.5	5.3	3.0	5.2
Mobile & Ohio	363	368	361	287	272	330	334	339	318	204	154	269	11.4	11.6	11.4	9.1	8.6	10.4
Nashville,Chattanooga & St.Louis	279	250	296	319	243	277	365	333	403	412	282	359	9.4	8.4	10.0	10.8	8.2	9.3
New Orleans & Northeastern	420	337	273	248	222	301	536	438	349	354	276	392	13.6	10.9	8.9	8.0	7.2	9.8
New Orleans Great Northern	207	300	234	132	121	197	238	342	239	136	107	210	6.3	9.2	7.3	4.1	4.0	6.2
Norfolk Southern	248	251	306	228	163	246	208	241	269	169	99	197	9.3	10.1	10.6	8.0	5.7	8.8
Northern Alabama	645	437	385	351	325	429	568	415	381	301	248	384	20.2	13.8	12.2	11.1	10.3	13.5
Seaboard Air Line	241	251	227	258	215	239	229	254	227	238	161	222	7.8	8.1	7.3	8.3	6.9	7.7
Southern Ry.	391	392	351	336	298	354	454	435	386	358	296	386	12.3	12.4	11.1	10.6	9.4	11.2
Tennessee Central	441	435	310	258	246	339	423	457	341	333	277	367	14.2	14.0	10.0	8.2	7.9	10.9

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TABLE C

AVERAGE NUMBER AND AVERAGE COST OF WOODEN CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF WOODEN CROSS TIE RENEWALS TO TOTAL WOODEN CROSS TIES IN MAINTAINED TRACK

Class I roads in the United States, by years, and for the average of the five years 1928 to 1932 inclusive

Note: All figures are exclusive of bridge and switch ties

Road	Average number of wooden cross tie renewals per mile of maintained track						Average cost of wooden cross tie renewals per mile of maintained track						Average precentage of wooden cross tie renewals					
	1928	1929	1930	1931	1932	5 year average	1928	1929	1930	1931	1932	5 year average	1928	1929	1930	1931	1932	5 year average
NORTHWESTERN REGION:																		
Chicago & North Western	198	183	173	136	108	160	$244	$218	$202	$162	$123	$189	6.9	6.4	6.0	4.7	3.7	5.5
Chicago Great Western	211	205	220	243	247	225	241	219	255	281	264	252	7.3	7.1	7.5	8.3	8.5	7.8
Chicago,Milwaukee,St.Paul & Pacific	302	287	214	185	162	230	311	307	231	205	167	244	10.4	9.9	7.4	6.4	5.5	7.9
Chicago,St.Paul,Minneapolis & Omaha	330	282	223	255	201	260	389	341	263	287	229	304	11.9	9.5	7.5	8.6	6.8	8.9
Duluth,Missabe & Northern (See note)	239	225	174	160	11	161	392	389	289	257	14	268	7.7	7.3	5.8	5.4	0.4	5.3
Duluth,South Shore & Atlantic	323	272	235	214	157	241	249	207	179	148	84	174	10.8	9.1	7.9	7.2	5.4	8.1
Duluth,Winnipeg & Pacific	426	386	266	321	246	329	294	282	202	230	167	235	14.2	12.9	8.9	10.7	8.2	11.0
Great Northern	220	205	190	168	140	185	260	254	224	190	138	213	7.0	6.4	6.0	5.3	4.4	5.8
Green Bay & Western	297	322	296	300	268	297	261	287	258	245	189	248	10.7	11.5	10.6	10.7	9.6	10.6
Lake Superior & Ishpeming	236	250	230	150	105	194	170	178	166	117	76	141	7.9	8.3	7.7	5.0	3.5	6.5
Minneapolis & St.Louis	203	150	122	102	101	135	262	173	139	112	111	159	6.7	5.0	4.0	3.4	3.3	4.5
Minneapolis,St.Paul & Sault Ste.Marie	271	238	222	173	164	214	263	259	271	193	173	232	9.2	8.1	7.5	5.9	6.0	7.4
Northern Pacific	180	169	124	103	101	135	220	208	156	127	122	166	6.2	5.8	4.3	3.6	3.5	4.6
Oregon-Washington R.R.& Nav.Co.	227	198	167	98	65	151	193	172	164	99	65	139	7.9	6.9	5.7	3.4	2.3	5.2
Spokane International	363	356	348	326	367	352	203	196	195	175	182	190	12.9	12.6	12.4	11.5	13.0	12.5
Spokane,Portland & Seattle	328	356	294	216	174	273	364	424	385	239	140	310	11.4	12.3	10.2	7.2	5.8	9.3
CENTRAL WESTERN REGION:																		
Alton R.R.	287	218	254	241	213	243	342	252	284	243	212	267	9.6	7.3	9.0	8.0	7.1	8.2
Atchison,Topeka & Santa Fe (See note)	180	176	160	117	82	143	265	253	221	155	104	199	6.2	5.8	5.3	3.8	2.7	4.7
Panhandle & Santa Fe (See note)	299	146	140	64	75	139	389	223	199	90	89	190	10.5	4.9	4.7	2.1	2.5	4.7
Chicago,Burlington & Quincy	170	168	151	134	106	146	223	218	195	170	133	188	5.5	5.4	4.9	4.3	3.4	4.7
Chicago,Rock Island & Pacific	150	156	128	106	38	115	180	173	141	116	42	130	5.0	5.2	4.3	3.5	1.3	3.8
Chicago,Rock Island & Gulf	206	184	185	98	44	137	284	254	296	161	74	206	7.5	6.6	6.1	3.3	1.5	4.7
Colorado & Southern	168	156	140	116	112	139	225	181	153	122	98	157	5.6	5.2	4.6	3.8	3.7	4.6
Denver & Rio Grande Western	303	198	175	162	130	193	318	234	210	190	141	219	9.7	6.4	5.6	5.2	4.2	6.2
Denver & Salt Lake	214	158	138	130	123	153	280	202	168	160	125	187	7.1	5.3	4.6	4.3	4.1	5.1
Fort Worth & Denver City	267	212	178	90	68	154	382	284	240	118	88	210	8.5	7.0	5.9	3.0	2.2	5.1
Los Angeles & Salt Lake	162	167	132	124	112	139	238	252	215	202	162	217	5.8	6.0	4.7	4.5	4.0	5.0
Nevada Northern	193	183	169	133	134	162	197	179	162	117	103	152	6.7	6.4	5.9	4.6	4.7	5.6
Northwestern Pacific	278	294	270	210	106	233	220	226	205	153	66	175	9.4	10.0	9.2	7.1	3.6	7.9
Oregon Short Line	176	177	151	111	59	135	209	216	198	147	78	170	6.3	6.4	5.4	4.0	2.1	4.9
St.Joseph & Grand Island	221	183	126	124	69	144	292	232	169	152	86	185	7.4	6.2	4.2	4.2	2.3	4.9
San Diego & Arizona	113	114	132	90	84	107	134	124	160	103	80	121	3.8	3.9	4.5	3.1	2.9	3.6
Southern Pacific Co.-Pacific Lines	210	202	164	137	97	162	300	261	198	164	105	205	7.2	6.9	5.6	4.7	3.3	5.5
Toledo,Peoria & Western	176	247	155	166	155	180	224	309	189	179	137	206	5.6	7.8	4.9	5.2	4.9	5.7
Union Pacific	192	162	123	108	85	134	221	206	169	147	118	172	6.8	5.8	4.3	3.8	3.0	4.7
Utah Ry.	196	201	234	187	110	185	282	267	321	244	128	248	6.7	7.7	9.0	7.2	4.2	6.9
Western Pacific	424	426	338	261	199	327	352	337	281	211	127	259	14.9	14.9	11.6	8.9	6.8	11.3
SOUTHWESTERN REGION:																		
Burlington-Rock Island	284	246	400	145	22	232	301	244	328	144	22	237	9.1	7.9	12.8	4.6	0.7	7.5
Fort Smith & Western	316	342	311	241	254	293	199	229	202	87	110	165	10.1	10.9	9.9	7.7	8.1	9.4
Fort Worth & Rio Grande	308	426	153	118	156	232	394	554	207	154	195	301	9.7	13.5	4.8	3.7	4.9	7.3
Gulf Coast Lines:																		
Beaumont,Sour Lake & Western	238	219	216	115	55	169	326	276	281	147	66	219	8.0	7.6	7.3	3.8	2.0	5.6
New Orleans,Texas & Mexico	280	240	224	126	93	193	361	302	293	161	105	249	9.2	7.8	7.3	4.1	3.0	6.3
St.Louis,Brownsville & Mexico	315	184	158	60	28	147	406	213	172	65	29	175	10.3	6.1	5.2	2.0	0.9	4.8
Gulf,Colorado & Santa Fe	139	205	191	125	59	143	172	260	227	142	72	174	4.3	6.3	5.9	3.9	1.8	4.4
International-Great Northern	281	214	204	167	93	191	346	268	235	190	91	225	9.4	7.1	6.8	5.6	3.1	6.4
Kansas City Southern	162	157	169	146	151	157	235	207	204	164	160	194	5.2	5.0	5.4	4.7	4.8	5.0
Texarkana & Fort Smith	94	117	140	156	90	119	167	195	168	175	98	160	3.0	3.7	4.5	5.0	3.2	3.9
Kansas,Oklahoma & Gulf	188	112	117	107	92	123	337	166	164	123	93	177	6.0	3.5	3.7	3.4	2.9	3.9
Louisiana & Arkansas (See note)	323	303	339	253	184	281	336	324	322	224	146	272	10.2	9.5	10.7	8.0	5.8	8.9
Louisiana,Arkansas & Texas	443	330	374	309	242	338	399	304	344	324	173	307	13.8	10.3	11.7	9.7	7.6	10.6
Midland Valley	240	208	165	112	76	161	391	306	224	128	80	227	7.7	6.5	5.1	3.5	2.4	5.0
Missouri & North Arkansas	263	326	250	240	178	250	168	245	175	124	77	156	8.4	11.0	8.0	8.1	5.7	8.2
Missouri-Kansas-Texas Lines:																		
Missouri-Kansas-Texas	214	201	168	98	129	162	272	263	223	99	101	192	6.8	6.4	5.3	3.1	4.1	5.1
Missouri-Kansas-Texas of Texas	265	234	152	87	108	167	334	307	202	88	82	200	8.3	7.4	4.8	2.7	3.4	5.3
Missouri Pacific	280	294	217	164	96	210	302	303	232	186	99	224	9.0	9.5	7.0	5.3	3.1	6.8
Oklahoma City-Ada-Atoka	d	d	404	108	97	203	d	d	347	69	61	159	d	d	12.9	3.6	3.1	6.5
St.Louis-San Francisco	142	204	168	124	167	161	159	228	190	137	166	176	4.6	6.6	5.4	4.0	5.4	5.2
St.Louis,San Francisco & Texas	234	334	149	133	164	186	293	441	194	170	191	235	7.4	10.5	4.7	4.2	5.2	5.9
St.Louis Southwestern Lines:																		
St.Louis Southwestern	378	332	260	90	75	220	529	455	312	111	91	289	11.9	10.5	8.2	2.8	2.4	6.9
St.Louis Southwestern of Texas	286	348	148	95	81	191	406	498	182	114	97	258	9.1	11.1	4.7	3.0	2.6	6.1
San Antonio,Uvalde & Gulf	210	241	240	225	132	210	281	304	307	288	158	267	7.5	8.5	8.3	7.8	4.6	7.3
Texas & New Orleans	238	222	173	139	99	174	326	291	223	176	112	226	8.6	8.9	6.3	5.1	3.7	6.4
Texas & Pacific	433	297	170	107	54	211	537	356	154	128	57	254	13.7	9.3	5.4	3.6	1.8	6.9
Texas Mexican	273	302	269	184	152	236	464	474	379	218	159	338	9.5	10.5	9.4	6.4	5.3	8.2
Wichita Falls & Southern	220	215	247	224	176	217	288	273	314	245	174	259	6.7	6.5	7.5	6.8	5.3	6.6

NOTE: Statement applies to Class I roads and includes consolidated data for Class I Roads merged during the period 1928 to 1932, as follows:

Baltimore & Ohio - includes Buffalo,Rochester & Pittsburgh and Buffalo & Susquehanna.
Grand Trunk Western - includes Chicago,Detroit & Canada Grand Trunk Junction and the Detroit,Grand Haven & Milwaukee.
New York Central -Inc.Evans.,Indianapolis & Terre Haute; Cincinnati Northern; Cleveland,Cincinnati,Chicago & St.Louis;
Michigan Central and Ulster & Delaware.
Pennsylvania - includes West Jersey & Seashore.
Reading Company - includes Perkiomen and the Port Reading.
Chesapeake & Ohio - includes Hocking Valley
Louisville & Nashville - includes Louisville,Henderson & St.Louis
Duluth,Missabe & Northern -includes Duluth & Iron Range.
Atchison,Topeka & Santa Fe - includes Kansas City,Mexico & Orient.
Panhandle & Santa Fe - includes Kansas City,Mexico & Orient of Texas.
Louisiana & Arkansas - includes Louisiana Railway & Navigation Company.

a Not Class I road prior to 1932.
b Estimated total cross ties in all maintained track not available.
c Not a Class I road prior to 1929.
d Not a Class I road prior to 1930.

Bureau of Railway Economics
Washington, D.C.
June,1933.

Appendix D

(4) TIE RENEWALS AVERAGES PER MILE MAINTAINED

W. J. Burton, Chairman, Sub-Committee; S. B. Clement, S. S. Roberts.

Because of requests for earlier publication of its tie renewal statistics, your Committee made a preliminary report on this subject which was published on page 71 of Bulletin 356 of June, 1933. This preliminary report included all data for United States railroads but did not include data for the three principal Canadian railroads because the latter was not then available. The Canadian data is given herewith in the form established by your Committee.

It is hoped that future reports, including the Canadian data, may be published not later than in the June Bulletin.

TABLE A

CROSS TIES LAID IN REPLACEMENT - CANADIAN ROADS

Calendar Year Ended December 31, 1932

Road	Wooden ties untreated (U)		Wooden ties treated (T)		Ties other than wood (S) and second hand	Total ties applied	Miles of maintained tracks (item 24)	Estimated total cross ties in all maintained tracks (item 25)	Equated gross ton-miles a
	Number	Average cost	Number	Average cost					
1	2	3	4	5	6	7	8	9	10
Canadian Railroads									
Canadian National	4 024 803	$ .57	658 889	$1.34	-	4 683 692	30 350.00	86 291 900	b
Canadian Pacific	1 517 608	.56	2 018 711	1.52	-	3 536 319	21 838.00	62 704 164	b
Temiskaming & Nor. Ontario	140 017	.78	-	-	-	140 017	567.53	1 645 900	b

a Maischaider formula. b Not reported to Tie Committee.

TABLE B

WOODEN CROSS TIES LAID IN REPLACEMENT (TREATED & UNTREATED) ON LEADING CANADIAN RAILROADS

Calendar Year Ended December 31, 1932

Road	Miles of maintained track occupied by wooden cross ties (Col.8-Table A)	Average number of wooden cross ties per mile of maintained track	Total number of wooden cross ties renewed 1932	Average number of wooden cross ties renewed per mile of maintained track	Weighted average cost per wooden cross tie	Average cost of wooden cross tie renewals per mile of maintained track	Average percentage of wooden cross tie renewals	Equated gross ton-miles per mile of maintained track	Cost of wooden cross tie renewals per thousand equated gross ton-miles
1	2	3	4	5	6	7	8	9	10
Canadian Railroads									
Canadian National	30 350.00	2 843	4 683 692	154	$ .68	$104.72	5.4	b	b
Canadian Pacific	21 838.00	2 871	3 536 319	162	1.11	180.00	5.6	b	b
Temiskaming & Nor. Ontario	567.53	2 900	140 017	247	.78	192.17	8.5	b	b

b Not reported to Tie Committee.

TABLE C

AVERAGE NUMBER AND AVERAGE COST OF WOODEN CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF WOODEN CROSS TIE RENEWALS TO TOTAL WOODEN CROSS TIES IN MAINTAINED TRACK

Canadian roads, by years, and for the average of the five years, 1928 to 1932 inclusive

Note: All figures are exclusive of bridge and switch ties

Road	Average number of wooden cross tie renewals per mile of maintained track						Average cost of wooden cross tie renewals per mile of maintained track						Average percentage of wooden cross tie renewals					
	1928	1929	1930	1931	1932	5 year average	1928	1929	1930	1931	1932	5 year average	1928	1929	1930	1931	1932	5 year average
Canadian Railroads																		
Canadian National	280	260	202	210	154	221	$274	$259	$210	$200	$105	$210	9.9	9.2	7.1	7.3	5.4	7.8
Canadian Pacific	250	241	220	210	162	216	248	263	327	297	180	263	8.8	8.6	7.9	7.3	5.6	7.1
Temiskaming & Nor. Ontario	a	a	229	236	247	244	a	a	174	186	192	190	a	a	7.8	8.1	8.5	8.4

Canadian National - includes Duluth, Winnipeg & Pacific; Atlantic & St. Lawrence and Grand Trunk Western.
Canadian Pacific - includes lines in Maine and Vermont.
a Average number of wooden cross-ties not available.

Appendix E

(5) RECOMMEND STANDARD SPACING OF SPIKE HOLES FOR TIES PRE-ADZED AND BORED FOR STANDARD RAIL SECTIONS 90-LB. TO 131-LB., INCLUSIVE, COLLABORATING WITH COMMITTEES IV, V AND XVII

E. E. Chapman, Chairman, Sub-Committee; H. F. Brown, R. E. Butler, H. R. Clarke. C. F. Ford, C. W. Greene, R. M. Jolley, C. S. Kirkpatrick, F. C. Krell, L. T. Nuckols, S. E. Shoup, L. L. Tallyn and J. W. Tate.

In 1933 the Railway Tie Association presented a request to the American Railway Engineering Association that consideration be given to so standardizing track and its parts for the more important rail sections as to result in standardized adzing and boring of ties.

The advantages for the tie producer were shown to be as follows:

"1. Regular and fairly uniform production of cross-ties is greatly to be preferred over intermittent production with slack periods followed by rush periods. The reasons are so patent that recital is almost superfluous. The best ties are those made by professional tie makers. Such men must be given fairly regular employment in order that they may live and remain in the producing territory. The expense of retaining tie makers during dull periods is a cost which must be not only borne by the producer but passed along to the user.

"Whether used treated or untreated, ties should be properly seasoned, which takes from two to twelve or more months; so that it is desirable for the producer to anticipate the demand and to manufacture some ties prior to specific orders. Such early production tends to care for the tie makers during dull periods, as well as smooth off the production peaks. The latter usually results in price competition but in little or no additional total production of good ties.

"The standard specifications for ties and their preservative treatment went a long way towards enabling the producer to get out ties between the seasons of active purchasing because the producer knew that if his ties met the specification he could find a buyer and that if impregnation became necessary before the ties were sold, he could give a standard treatment and still be reasonably sure of a sale.

"But the new and growing practice of pre-adzing and pre-boring has taken away part of the benefit from standard specifications and made it much less possible to treat ties prior to specific orders, on account of the great variation in the required spacing and arrangement of the spike holes. No two railroads specify the same pattern, even for identical rail sections, cant of tie plates, etc., with the result that if a producer makes ties without orders, and it becomes necessary to treat such ties, they must be either treated without boring, or bored to some template which will very likely be unsatisfactory to many later prospective buyers.

"Wood preserving plants can also operate to best advantage under fairly uniform demand instead of intermittent demand, dull, and rush periods.

"The treating plants also would benefit from standard machining because of the reduction in the number of necessary templates, knives and bits, and in the labor of making changes to accommodate different patterns of adzing and boring.

"Any reduction in the number of such patterns through standardization is therefore desirable from the standpoints of both producer and treater, even though a single standard is not possible."

The advantages for the railroads were stated to be as follows:

"2. In the long run, all producer costs must be borne by the purchaser. A corollary is also true, i.e., in the long run what benefits the producer will benefit the purchaser. This is only another way of stating the old familiar law of 'Supply and demand'. Increase the supply, or lower the cost, and the price (with a given demand) will tend downwards.

"Removal or lessening of the peak demands for ties will tend to ease those wasteful buying periods which have always come when business 'opens up.'

"Simplification and standardization of adzing and boring will also benefit railroads through the reduction in stocks and the greater flexibility and ease of distribution of their ties, just as similar standardizations of other materials have been of benefit.

"The smaller roads may purchase standard adzed, bored and treated ties, knowing that what is furnished will exactly fit their needs. While the larger roads may prefer to buy their ties before treatment, and to carry them during the seasoning period, the opportunity for the smaller roads to buy standard adzed, bored and treated ties will react to benefit both the small and the large roads.

"The opportunity for the advance producer to treat ties as soon as they are sufficiently seasoned should remove the tendency to hold unsold ties too long before giving preservative treatment, with the resulting (but frequently unobservable) deterioration and lessened service life. Even though the smaller roads were the only ones to purchase black ties, the benefit from longer service for their ties would react to lessen the total demand for ties and thus benefit the larger roads as well.

"An almost complete lack of agreement in the specified dimensions, even for the same rail sections, tie plate cant, etc., is to be noted. The very small differences in many cases indicate what happens when separate men work independently on the same problem and they furnish a good example of the desirability of the preparation of standards at the time a new practice is being introduced."

The results secured from the questionnaire sent out by the Railway Tie Association committee are shown by Exhibit A and substantiate the statement regarding the radical lack of agreement on spacing bored holes and adzing ties.

In order to bring out this lack of agreement graphically, the locations of holes in ties and the lengths of adzed surfaces for two rail sections have been plotted. These are the 110-lb. R.E. and 130-lb. R.E. rail sections (see Exhibit B).

The causes for differences of spacing holes and adzing of ties are as follows:

1. Design of rail:
   - (a) Width of base.
   - (b) Width of head.
   - (c) Height of rail where canted tie plates are used.

2. Design of tie plate:
   - (a) Canting:

     There are different cants in use as follows:

     (1) Flat (4) 1 in. in 38.8 in.
     (2) 1 in. in 44 in. (5) 1 in. in 24 in.
     (3) 1 in. in 40 in. (6) 1 in. in 20 in.

     The A.R.A. standard coning of car and locomotive wheels is 1 in 20. One railway maintains 1 in 38 and one 1 in 16.
   - (b) Length and eccentricity of tie plate:

     Various railroads use tie plate designed for ties made of hard or softwood, heavy or light loads, and perhaps for other variables.
   - (c) Varied locations of spike holes due to design by different individuals:

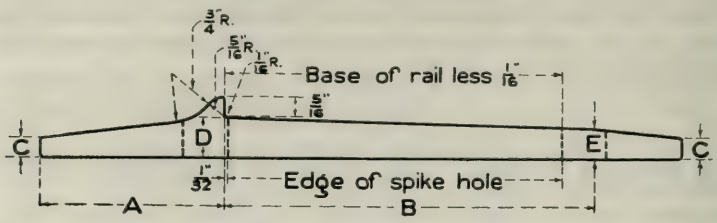
     The graphs show the radically different locations for the same rail sections used by different companies.
   - (d) Location of V ribs in bottom of tie plates:

     The general recommended design for tie plates as shown by 1929 A.R.E.A. Manual is as follows:

"TABLE OF DIMENSIONS FOR TIE PLATES, INCHES

Length of plates	*Range of rail bases*	*Same for flat and canted plates*			*Flat plates*	*Canted 1 in 40*		*Canted 1 in 20*	
		A	*B*	*C*	*D & E*	*D*	*E*	*D*	*E*
9	4¾ to 5	2⅜	5⅜	5/16	9/16	9/16	7/16	¾	15/32
9½	4¾ to 5⅛	2⅝	5 9/16	5/16	⅝	⅝	½	¾	15/32
10	4⅞ to 5½	2⅞	5¾	5/16	⅝	⅝	15/32	¾	15/32
10½	5⅛ to 5¾	3	5 15/16	⅜	11/16	11/16	17/32	13/16	17/32
11	5⅜ to 6	3¼	6⅛	⅜	11/16	11/16	17/32	13/16	½
11½	5¾ to 6¼	3½	6 5/16	⅜	¾	¾	19/32	13/16	½
12	6 to 6½	3⅝	6½	⅜	¾	¾	19/32	13/16	½

"Data for Designing Tie Plates



Ribs not exceeding ¼ in. deep are desirable on bottom of plate.

Thicknesses shown are exclusive of any ribs or corrugations on bottom.

On hardwood ties, widths of 7 in. or 7½ in. are recommended.

If splices are slotted for spiking, spike holes in tie plates shall be located accordingly.

Spike holes shall be made the size of the spike plus ⅛ in., and in high carbon hot worked plates, spike holes shall have a fillet radius of $\frac{1}{16}$ in.

Plates may be rolled with a camber or crown of $\frac{1}{16}$ in. if desired by the purchaser.

Where plate is cambered or crowned the shoulder height, $\frac{5}{16}$ in. is measured at center of plate.

For extra heavy service add ⅛ in. to dimensions D and E."

3. Design of Spikes:

The standard spikes shown on page 254 of 1929 Manual are $\frac{9}{16}$ in. and ⅝ in. square. Spikes with thickened shanks for the portion above tie (to combat neck grooving) are in use. Some screw spikes are also in service.

The standard spike sizes should not cause any trouble due to small difference in section.

4. Design of joint bars:

The designs of joint bars are so varied that each section has to be considered separately. The present trend is to standardize on joint bars in which the bottom toes do not protrude beyond the base of the rail. Standard bolt spacing will assist in a standard for pre-boring.

5. Ties:

The Standard Cross-ties, as shown on page 118 of A.R.E.A. 1929 Manual, are given below:

Size	*Sawed or Hewed Top, Bottom, and Sides*	*Sawed or Hewed Top and Bottom*
1		6 in. thick by 6 in. wide on top
2	6 in. thick by 7 in. wide on top	6 in. thick by 7 in. wide on top
3	6 in. thick by 8 in. wide on top	6 in. thick by 8 in. wide on top
		7 in. thick by 7 in. wide on top*
4	7 in. thick by 8 in. wide on top	7 in. thick by 8 in. wide on top
5	7 in. thick by 9 in. wide on top	7 in. thick by 9 in. wide on top
6	7 in. thick by 10 in. wide on top	7 in. thick by 10 in. wide on top

The standard sizes in general use are 1, 2, 3, 3A, 4 and 5.

Discussion

There are only about twenty creosoting plants owned and operated by about ten railroads in the United States. Other railroads obtain their treatment at commercial plants. These few railroads who treat part or all of their own ties produce a very small portion of the ties treated each year, so that standardizing of the boring and adzing of ties is important to most railroads and to a large part of the total treated tie production.

A table has been prepared showing what may possibly be accomplished if recommended standards of the Manual are followed. If the present standards were adhered to,

* Railways which specify both 6 in. × 8 in. and 7 in. × 7 in. ties manufactured on top and botton only and which desire to separate the 6 in. from the 7 in. ties will designate the 7 in. × 7 in. as Size 3A.

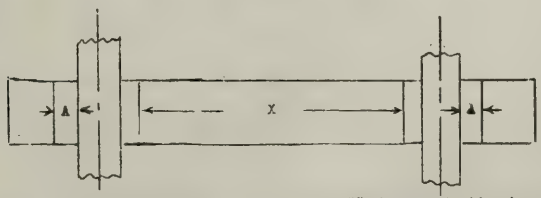
it would be possible to adze all ties with a 12.5 in. adzing length and this would care for present A.R.E.A. standards as to length of tie plates. In order to meet sizes of tie plates in use, or likely, the adzing space should be 16 in. in length, with 9 in. to the outside and 7 in. to the inside of the rail center to care for eccentricity of plates.

The report of the Special Committee on Stresses in Railroad Track of 1925 indicates that on tangent track plates sink down into the ties more on the inside of rail than on the outside, with a tendency for the gage of the track to tighten. On curved track the opposite is the rule. This was checked with both the flat tie plates and the plates which had a cant of 1 in 20. The recommendation of the Special Committee on Stresses in Track was that the eccentricity of tie plates should not be over about 3/8-in.

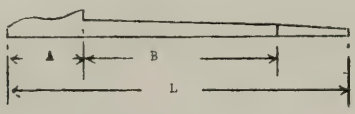
It will be noted from the graphs for 110-lb. R.E. and 130-lb. R.E. rail sections that there are radically different locations for spike holes across the width of the plates, and that also some roads are using three spikes on both the outside and the inside of the rail while others use three spikes on the outside and two on the inside of the rail. Also, that where four spikes per tie plate are used, there are variations in spacing of from 1 3/4 to 4 1/2 in. Consideration should be given to a standard distance between the spike holes at each edge of the rail base. This dimension may depend upon the bolt spacing of the rail joint. A good distance from the standpoint of the tie would be 3 in. or 3 1/2 in.

In the following tabulation pertinent dimensions are given for adzing to meet the existing standards of the Association. However, a single standard of adzing for all rail sections is recommended.

Weight of rail	Dimensions of rail, in. Width of base	Height	Distance between center lines of rails at base, ft-in. Flat	1 in 20	Canted 1 in 40	Maximum length outside of tie plates, ft-in.
90# ARA	5 1/8	5 5/8	4-11 1/16	4-11 11/16	4-11 11/32	5- 9 15/16
100# RE	5 3/8	6	4-11 3/16	4-11 25/32	4-11 31/64	5-10 29/32
110# RE	5 1/2	6 1/4	4-11 9/32	4-11 29/32	4-11 19/32	5-11 13/32
112# RE	5 1/2	6 5/8	4-11 7/32	4-11 27/32	4-11 35/64	5-11 27/32
130# RE	6	6 3/4	4-11 7/16	5- 0 7/64	4-11 25/32	6- 1 7/64
131# RE	6	7 1/8	4-11 1/2	5- 0 13/64	4-11 55/64	6- 1 29/64



Weight of rail	Tie plate dimensions same for flat and canted, in. L	A	B	Distance "X" between inside edges of tie plates, ft. in. Flat	Canted 1 in 20	Canted 1 in 40	Maximum cut outs necessary in tie widths, in.
90# ARA	9 1/2	2 9/16	5 9/16	4-2 5/16	4-2 15/16	4-2 19/32	9 13/16
100# RE	10	2 7/8	5 3/4	4-2 5/16	4-2 29/32	4-2 39/64	10 19/64
110# RE	10 1/2	3	5 15/16	4-1 25/32	4-2 13/32	4-2 3/32	10 53/64
112# RE	10 1/2	3	5 15/16	4-1 23/32	4-2 12/32	4-2 3/64	10 53/64
130# RE	11 1/2	3 1/2	6 5/16	4-1 7/16	4-2 7/64	4-1 25/32	11 27/32
131# RE	11 1/2	3 1/2	6 5/16	4-1 1/2	4-2 7/32	4-1 55/64	11 27/32



Recommendations

In view of the interdependence between rail joint and tie plate design and the fact that as far as the tie is concerned, the standard for pre-boring and adzing can be made to conform to the design requirements for joints and tie plates, your Committee respectfully suggests that this subject be reassigned to the proper committee, with instructions to consider the following suggestions in preparing a standard or standards of tie plates which will result in standardized adzing and boring:

1. A single standard of cant.

2. A standard distance between centers of spike holes in all tie plates at the edges of the rail base.

3. The lengths and eccentricity of tie plates to be standardized.

4. A standardized location for the grooves cut in the cross-ties, both as to distance between the two grooves under each rail and the distance (gage) between the grooves under one rail and those under the other rail so that all cross-ties may be pre-grooved to a single standard regardless of the rail section to be used, making the necessary accommodations for different rail sections in the designs of the tie plates for different rail sections.

5. To particularly expedite standards for plates and boring for the new 112-lb. and 131-lb. rail sections.

Exhibit A

Tabulation of Data from Questionnaire

Rail Section	Road	Dimension A In.	Dimension B In.	Dimension C Ft. In.	Dimension D In.	Diameter Spike Hole In.	Diameter Hole In.	No. Hole	Cant of Plate 1 in	Pattern
130# R.E. (Sec. 13025, 6"x6½"x2 15/16")	A.T.&.S.F.	4½	6 11/16	4 - 4-15/16	12½	5/8	1/2, 9/16	8	44	A
	B. & M.	4	6 3/4	4 -5-3/16	15	5/8	9/16	4	20	B
	C.RR of N.J.	4	6 41/64	4 - 5-9/32	14	5/8	1/2	8	20	A
	C.N.St.P.& P.	1½	6 9/16	4 - 5-1/16	14	9/16	7/16	12	38.8	M
	D.L.& W.	1½	-	-	14	5/8	9/16.	8	40	J
	Erie	3½	6 11/16	4 - 4-15/16	14	5/8	1/2, 9/16	16	40	L
	N.Y.N.H.& H.	4	6 5/8	4 - 5 3/8	15	5/8	1/2	8	20	A
	N.& W.	4. 3	6 11/16	4 - 5 5/16	16	5/8	1/2	12	20	N
	N. P.	3 3/4	6 21/32	4 - 5 3/16	12	9/16	7/16,1/2	4	24	B
	P. & R.	4½	-	-	14	5/8	9/16	8	20	-
	U. P.	3	6 5/8	4 -5 1/32	13	5/8	7/16	8	40	E
130# F.S. (Sec. 13031, 5½"x6 5/8"x3")	B. & L.E.	3 9/16	11 13/16	4 -0 3/32	16	5/8	5/8	8	40	A(GEO)
	N. & W.	3	6 3/16	4 - 5 15/16	16	5/8	1/2	12	20	N
127# (Sec. 12722. 6¼"x7"x3")	Big 4	3½	6 29/32	4 - 4 53/64	13½	5/8	9/16	4	44	B
	K.C.S.	3 3/8,2¼	6 7/8	4 - 5 3/16	13½	5/8	1/2,9/16	8	20	C
136# (Sec. 13633, 6½"x7"x2 15/16")	L.V	4	7 3/16	4 - 4 3/4	16	5/8	1/2	10	20	H
110# R.E. (Sec. 11025, 5⅝"x6¼"x2 25/32")	A.T.& S.F.	4½	6 5/32	4 - 5 5/16	12½	5/8	1/2,9/16	8	44	A
	C.& N.W.	3 13/16	6 1/4	4 - 5 7/16	12½	5/8	1/2	8	40	F
	C.B.& Q.	3	6 5/32	4 - 5 1/4	12	5/8	7/16,1/2	8	44	E
	C.R.I.& P.	3½	6 5/32	4 - 5 5/16	12½	5/8	1/2	8	44	A
	Erie	3½	6 5/16	4 - 5 1/4	14	5/8	1/2,9/16	8	40	A
	M.St.P.& SSM	3 3/4	6 3/16	4 - 5 5/8	14	5/8	1/2	8	20	A
	M.P.	3	6 5/32	4 - 5 11/32	12	5/8	9/16	8	40	A
	N.Y.C.& St.L.	3½	6 3/16	4 - 5 1/4	14	5/8	1/2	8	40	F
	P.M.	3 1/4	6 1/8	4 - 5 3/8	14	5/8	9/16	8	40	F
	St.L.-S.F	3½	6	4 - 5 7/16	13½	5/8	7/16,1/2	8	44	A
	T.& N.O.	4	-	-	12	5/8	1/2	8	40	-
	T.& P.	3 1/4	6	4 - 5 3/8	11½	9/16	1/2	4	40	B
	U.P.	3	6 1/8	4 - 5 11/32	13	5/8	7/16	8	40	E
	Wabash	4	6 7/32	4 - 5 7/32	14	5/8	1/2	8	40	F

Rail Section	Road	Dimension A In.	Dimension B In.	Dimension C Ft.	Dimension C In.	Dimension D In.	Diameter Spike In.	Diameter Hole In.	No. Hole	Cant of Plate 1 In.	Pattern
110# (Sec. 11036, 5½"x6½"x2 3/4")	G. U.	3 3/4	-		-	14	5/8	7/16,1/2	8	40 44	-
107# (Sec. 10734, 5½"x6 1/8x2 3/4")	N.Y.N.H.&H.	4	6 1/8	4	- 5 1/2	14	5/8	1/2	6	20	I
105# Sec. 10523, 5 3/8x6x2 3/4")	D.L.& W.	1 3/4	-		-	14	5/8,7/8	9/16,7/8	8	40	J
105# (Sec. 10524, 5½"x6"x3")	Big 4	3 1/2	6 5/32	4	- 5 17/32	13½	5/8	9/16	4	44	B
100# ARA-A (Sec. 10020, 5½"x6"x2 3/4")	B. & M.	3	6 1/8	4	- 5 1/2	14	5/8	9/16	8	20	A
	C.RR N.J.	4	6 1/8	4	- 5 1/16	14	5/8	1/2	8	None	A
	C.B.& Q.	3	6 5/32	4	- 5 1/4	12	5/8	7/16,1/2	8	44	E
	CMStP&P	3 1/2	6 1/16	4	- 5 3/8	14	9/16	7/16	8	44	A
	C.R.I.& P.	3 1/2	6 5/32	4	- 5 1/16	12½	9/16	1/2	8	None	A
	Erie	3 1/2	6 5/16	4	- 5 1/4	14	5/8	1/2,9/16	8,16	40	A
	M.P.	3	6 5/32	4	- 5 11/32	12	5/8	9/16	8	40	A
100# R.B. (Sec. 10025, 5 3/8"X6"x2 11/16")	A.C.L.	2 3/4	-		-	11	9/16	1/2	8	44	A
	K.C.S.	3 3/8,2¼	6	4	- 5 11/16	13½	5/8	1/2,9/16	8	20	C
	MS&P&SSM	3 3/4	6 1/8	4	- 5 11/16	14	5/8	1/2	8	20	A
	N.P.	3 3/4	6 1/32	4	- 5 7/32	12	9/16	7/16,1/2	4	None	B
	St.L.-S.F.	3 1/2	5 15/16	4	- 5 1/4	13½	5/8	7/16,1/2	8	44	A
	U.P.	3	6	4	- 5 3/8	13	5/8	7/16	8	44	E
100# R.B. (Sec. 10030, 5 9/64"X5 41/64"x2 21/32")	N. & W.	2 3/4,3	5 7/8	4	- 5 3/4	16	5/8	1/2	10	20	K
100# Sec. 10035, 5 9/64"x5 45/64"x2 9/16")	C. & N.W.	3 13/16	5 49/64	4	- 5 19/32	12½	5/8	1/2	8	40	F

Rail Section	Road	Dimension A In.	Dimension B In.	Dimension C Ft.	Dimension C In.	Dimension D In.	Diameter Spike In.	Diameter Hole In.	No. Hole	Cant of Plate 1 In.	Pattern
100# (Sec 10036, 5"x5"x2 3/4")	C N	3 3/4	-		-	14	5/8	7/16,1/2	8	44	-
100# ASCE (Sec. 10040, 5¾"x5¾"x2¾")	C M St P.&P	3 1/2	6 1/16	4	- 5 3/8	14	9/16	7/16	8	44	A
90# RE (ARA-A) (Sec. 9020, 5 1/8x5 5/8x2 9/16")	C.B.&Q	3	5 25/32	4	- 5 1/2	12	5/8	7/16,1/2	8	44	E
	C.M.St P & P	3 1/2	5 25/32	4	- 5 1/2	12	9/16	7/16	8	44	A
	C.R.I.& P.	3 1/2	5 3/4	4	- 5 1/4	12½	9/16	1/2	8	None	A
	G.C.L.	3 1/2	5 3/4	4	- 5 3/8	12	9/16	7/16	8	40	A
	M.St.P.&S.S M.	3 3/4	5 7/8	4	- 5 13/16	14	5/8	1/2	8	20	A
	M.K.T.	4	5 11/16	4	- 5 5/16	11½	9/16	1/2	8	44	A
	M.P.	3	5 13/16	4	- 5 7/16	12	5/8	9/16	8	40	A
	N.Y.C.& St.L.	4 1/4	5 13/16	4	- 5 3/8	14	5/8	1/2	8	44	F
	P.M.	3 1/4	5 3/4	4	- 5 7/16	14	5/8	9/16	8	40	F
	T.&.N.O.	4	-		-	12	5/8	1/2	4	40	-
	T.& P	3 1/4	5 11/16	4	- 5 3/8	11	9/16	1/2	4	40	B
	U.P.	3	5 3/4	4	- 5 1/2	13	5/8	7/16	8	40	E
	Wab.	4	5 25/32	4	- 5 3/8	14	9/16	7/16	8	40	FA
90# ASCE (Sec 9040 5 3/8x5 3/8 x 2 5/8")	Big 4	3 1/8	6 1/16	4	- 5 1/8	13½	5/8	9/16	4	None	B
	C.RR N.J.	2 1/4	6	4	- 5 1/8	14	5/8	1/2	8	None	C
	M.K.T.	4	5 15/16	4	- 5 3/16	11½	9/16	1/2	8	44	A
	StL-S F.	3 1/2	5 15/16	4	- 5 1/4	13½	9/16	7/16,1/2	8	None	A
90# S.F. (Sec. 9021, 5 3/16"x5 5/8"x2 9/16")	A.T.&.S.F.	4 1/2	5 13/16	4	- 5 3/16	12½	9/16	7/16,1/2	8	None	A
90# (Sec. 9035, 5 3/32"x5 17/32"x2 13/32")	C.& N.W.	3 13/16	-	4	- 5 19/32	12	5/8	1/2	8	40	F
90# (Sec. 9030, 5 49/64"x5 17/64"x2 9/16")	N.P.	3 3/4	5 27/64	4	- 5 21/32	12	9/16	7/16,1/2	4	None	B

Rail Section	Road	Dimensions A In.	B In.	C Ft. In.	D In.	Diameter Spike In.	Hole In.	No. Hole	of Plate 1 In.	Pattern
90 # (Sec. 9024, 5"x5 3/8"x2 5/8")	G. N.	3 3/4	-	-	14	5/8	7/16,1/2	8	40 44	-

Data for rail sections lighter than 90# is not given. There is fully as much lack of standardization with the lighter sections as is indicated above for the heavier sections.

Explanation of References

Dimension A is distance across width of tie between centers of spike holes at the edge of rail base.

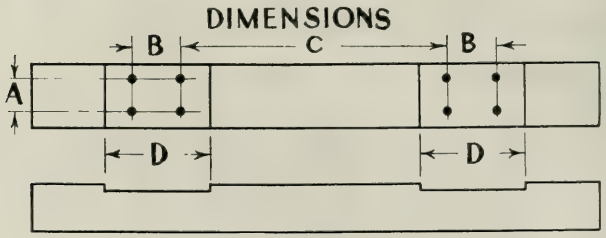
Dimension B is distance along length of tie between centers of spike holes at the edge of rail base.

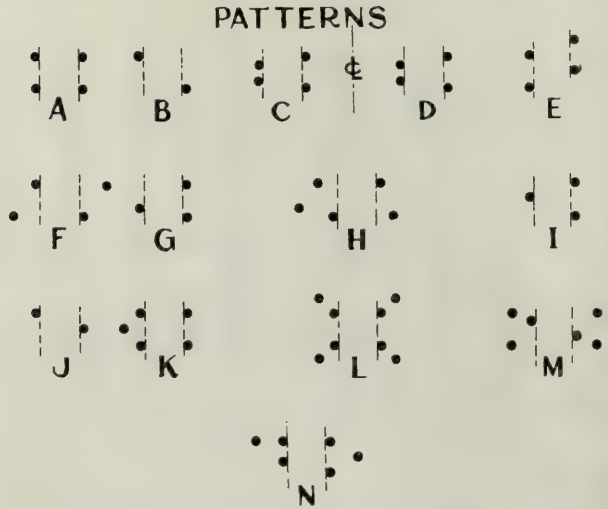
Dimension C is distance along length of tie between the centers of inside spike holes at the two rails.

Dimension D is the length of adzed surface.

The patterns referred to are as follows:

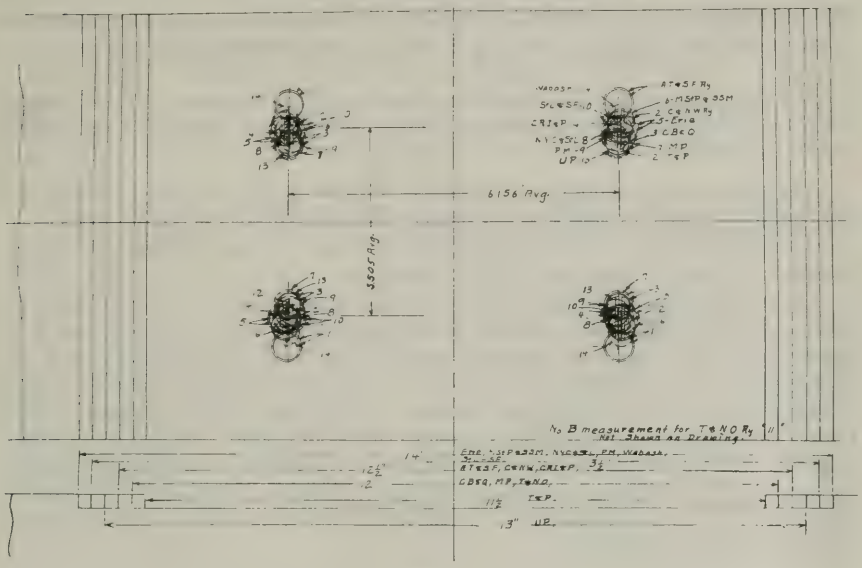
ILLUSTRATIONS OF DIMENSIONS AND PATTERNS





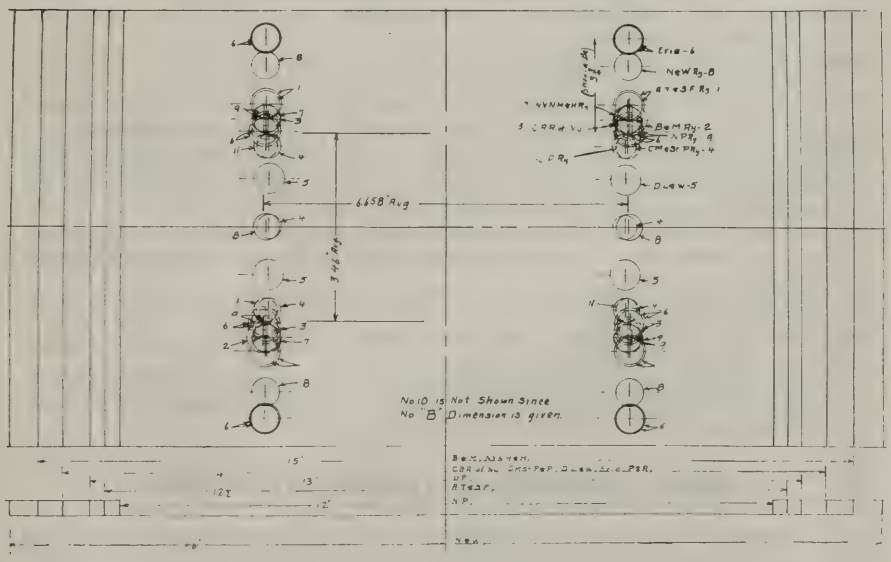
LOCATION OF SPIKE HOLES AND WIDTH OF ADZED SURFACE

For Rail 110# RE, Sec. 11025, Base 5 1/2 in., Height 6 1/4 in., Ball 2 25/32 in.



LOCATION OF SPIKE HOLES AND WIDTH OF ADZED SURFACE

For Rail 130# RE, Sec. 13025, Base 6 in., Height 6 1/4 in., Ball 2 15/16 in.



Appendix F

(8) A METHOD OF PREDICTING TIE RENEWALS, INCLUDING A PERIOD OF CHANGE FROM UNTREATED TO TREATED TIES

E. L. Crugar, Chairman, Sub-Committee; John Foley, W. C. Bolin, H. F. Brown, C. S. Kirkpatrick, A. F. Maischaider, L. J. Riegler, S. S. Roberts, S. E. Shoup, W. W. Wysor.

The method of predicting tie renewals as outlined in the following report is not new, but an attempt has been made to simplify the procedure by the use of tables.

The renewal rates as set up in the report are based on data available on the performance of untreated and zinc-chloride treated ties.

Cross-ties inserted during the past several years on most roads have been treated by ways and means which are considered improvements over earlier practices, and it is reasonable to expect that these improvements will bring about a material increase in the average life of ties. In addition to the methods of treatment to stop natural deterioration of ties, improvements have been made in design of the track structure bringing about a further increase in the average life by reducing mechanical wear. The necessary information is not at present available which will give an indication of the manner in which the ties, with the improved treatment and better protection, will fail or the rate at which they will require replacement. It has therefore been necessary to make assumptions as to their performance.

DEFINITIONS OF TERMS

Tie-Years.—This term is used to indicate the unit of service produced by one tie in track one year. One tie in track 10 years produces 10 tie-years; two ties in track 5 years produce 10 tie-years, etc.

Average Life.—The average life of a group of ties is found by dividing the total tie-years produced by the individual ties, by the total ties in the group.

Normal Annual Renewals.—Normal annual renewals is the number of ties required annually to maintain the track without a change in standard of maintenance.

Uniform Annual Renewals.—This term refers to the renewals in any one year after the group of ties has been in service long enough to produce a condition whereby the renewals become the same for every year. This value is always equal to the number of ties in service, divided by the average life.

Life of Tie.—The life of a tie as used herein is the number of years between the end of the year during which it was inserted and the end of the year during which it was removed.

Age Interval.—The age interval used is one year, taken from the end of one year to the end of the following year.

7-Year Ties (8-Year Ties, etc.)—This term is used for convenience to indicate a group of ties having an average life of 7 years, etc.

7-Year Tie (8-Year Tie, etc.)—This term is used for convenience to indicate a tie in a group of ties having an average life of 7 years. The term is hypothetical and does not mean that the life of the individual tie is 7 years.

GENERAL DISCUSSION OF RENEWAL PREDICTIONS

Tie renewals for any year can be predicted, when sufficient data are available, by calculating the number of ties in track which will be removed during that year. Such a prediction when based on actual records of past renewals is of value for checking the number of ties requested on the basis of field inspection. Within practical limits the prediction can be used in making purchases of ties for future requirements.

Studies of tie renewals have been made since the early part of the twentieth century in an effort to establish the law of probability governing the rate of failure, and these have changed the old conceptions as to the order in which ties fail. They have also shown that the rates of failure in different classes are similar when compared to the average lives of the ties in the groups.

Renewals are studied by dividing ties into groups of similar kinds or classes. A renewal curve is developed by reducing the number of ties removed annually to a per cent of the total in the group. This curve is more easily visualized when it is shown graphically as in Fig. 6, which is a comparison of the accumulated renewals for groups having average lives of 8, 12, 16, 20, and 24 years.

Sufficient data are available to show that the only difference between untreated and treated ties in connection with making a renewal prediction is the difference in their average lives.

Renewal Cycles.—To illustrate how tie renewals fluctuate from year to year in definite cycles, the two curves shown in Fig. 1 were plotted from a prediction of renewals on two sections of track, each constructed with 1,000,000 ties. On one section the renewals were made continuously with 7-year untreated ties, and on the other with 24-year treated ties. If renewals are predicted for a long enough period of time, they will eventually become uniform as shown in Fig. 1. In connection with this illustration, it is interesting to note that during the first fifty years after date of construction, 6,744,738 7-year ties and only 1,632,904 24-year ties were used for renewals.

Effect of Change in Class of Ties.—To illustrate the theoretical effect of a change from the use of untreated to treated ties, it was assumed that the section of track constructed with 7-year ties as referred to in the preceding example was maintained with 7-year ties for 19 years, and that after that time all renewals were made with 24-year treated ties. The effect of this change is shown in Fig. 2. The oscillations of the renewal curve continue until eventually it reaches a uniform renewal line.

Renewal Prediction.—Fig. 3 illustrates a prediction on a road where it was known there were 1,241,149 ties in track at the end of 1931. The ties in track on this road were untreated and zinc-chloride and creosote treated. The average life of the creosoted ties inserted prior to 1931 was estimated at 18 years. Beginning with 1932, all ties were pre-adzed and bored and were given a heavier treatment, and for these reasons the estimated average life was increased to 23 years. The calculations were made by working out the renewals of the four classes separately, using the actual renewal figures prior to 1932 and the calculated figures beginning with the year 1932. The smoothness of the prediction curves as shown in Fig. 1 and 2 is lost to some extent in the actual prediction curve due to the mixture of the four classes of ties.

Since treated ties are being used on this road, the theoretical effect on renewals by a change to the use of untreated ties is shown by the dashed line. It was assumed that renewals were made from 1932 to 1938 with the 23-year treated ties and from that time on with 8-year untreated ties. While this prediction is in the reverse order of the problem assigned to the Committee, it shows clearly the result which could be expected if a change were made from the use of treated ties with a long average life to untreated ties with a short average life.

Comparisons of Ties Renewed Per Mile.—For a number of years records have been published showing the ties renewed annually per mile on various roads. All we know from these records is that some roads use more ties per mile than others. A comparison of renewals per mile on two roads does not show the existing tie conditions. The only way this can be shown is by a comparison of the renewal predictions. Fig. 4 illustrates, in theory, renewal predictions on two roads. During the year 1932, Road A

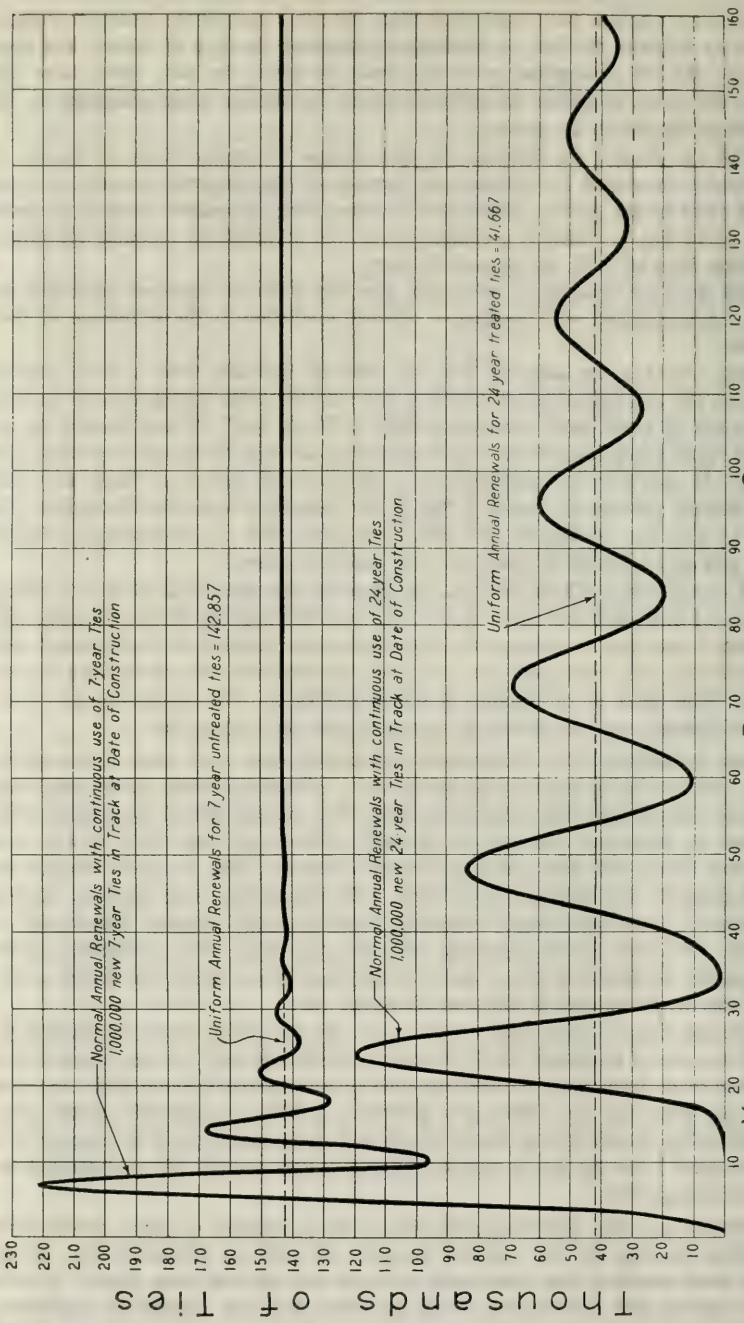


Fig. 1.—Illustration of predictions of tie renewals on two sections of track, one constructed and maintained with 7-year ties and the other one with 24-year ties.

used 179 ties per mile, while Road B used only 101 ties per mile. Each road had the same number of ties in track and had been using the same class of ties, but Road B had started the use of the longer life treated ties several years prior to Road A so that the renewal cycles were not the same. If a comparison of the ties renewed per mile on these two roads were made without the prediction curves, it would lead to erroneous conclusions.

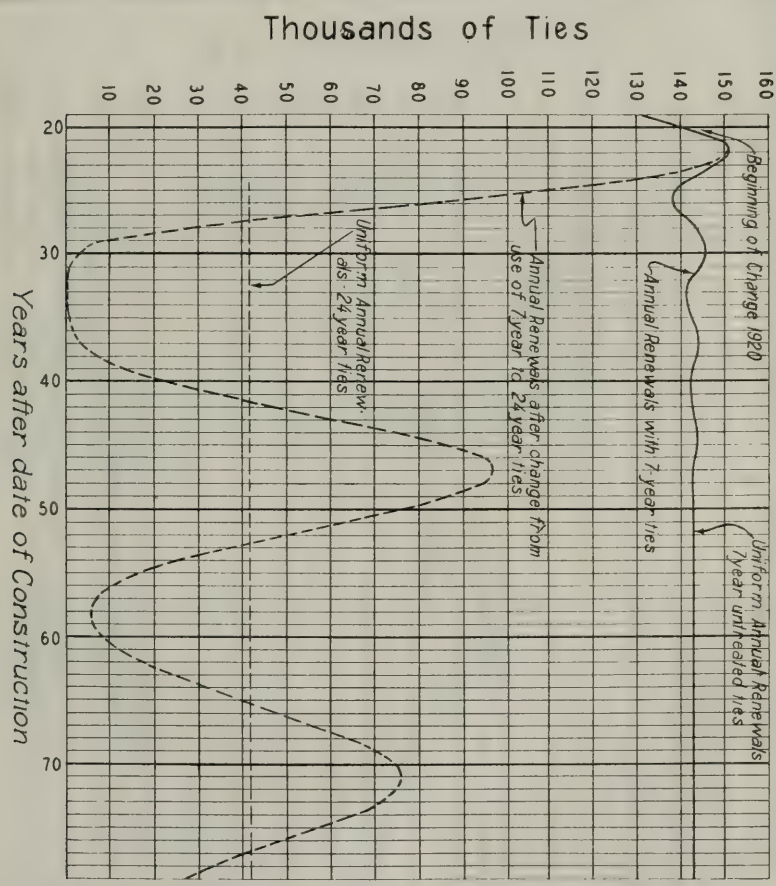


Fig. 2.—Illustration of the effect on renewals required if a change from 7-year ties shown in Fig. 1 is made to 24-year ties at the beginning of the 20th year.

Deferred Maintenance.—Without the use of a prediction of renewals it is possible to make a comparison which does not reflect the true conditions of maintenance. To illustrate this, assume that the prediction shown by the solid line in Fig. 3 has been equalled in actual practice. During the three years 1950, 1951, and 1952, 127,143 ties were renewed. If this three-year period is compared with the record for the three years 1943, 1944 and 1945, during which time 211,539 ties were renewed, there would appear to be deferred maintenance during 1950, 1951, and 1952 to the extent of 84,396 ties. Actually the lower renewals during the latter years were due to the normal fluctuations of the renewals rather than to any deferred maintenance.

Annual Renewal Rates.—Table 1 gives the annual renewal rates expressed as a percentage of the total ties in group, for groups having average lives from 7 to 30 years. These rates when applied to each group of ties separately will give the number of ties to be removed each year from the time the group was inserted until the last ties are removed. This table is based on a set of renewal curves developed for the purpose of predicting renewals. There is an individual curve for each average life. To show the

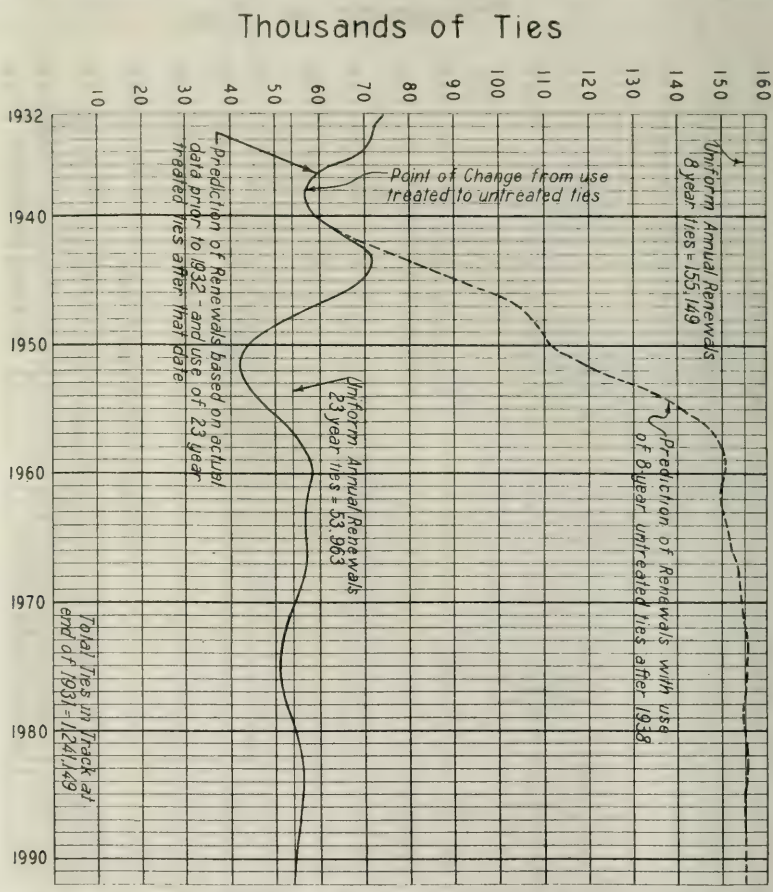


Fig. 3.—Illustration of predicted renewals after 1932 on a road having 1,241,149 ties in track. This figure also shows what effect on renewals would be, were a change made from 23-year ties to 8-year ties in 1938.

relation between the percentage of ties removed and the percentage of average life, the cumulative renewal curves for average lives of 8, 12, 16, 20, and 24 years are plotted in Fig. 5. These curves, in cumulative form, are based on the theory that the longer the average life the more nearly vertical will be the central part of the curve expressing the relation between the percentage of ties removed and the percentage of average life. This theory is supported by data now available for ties producing average lives up to about 18 years and it is assumed that it will hold true with the longer life ties.

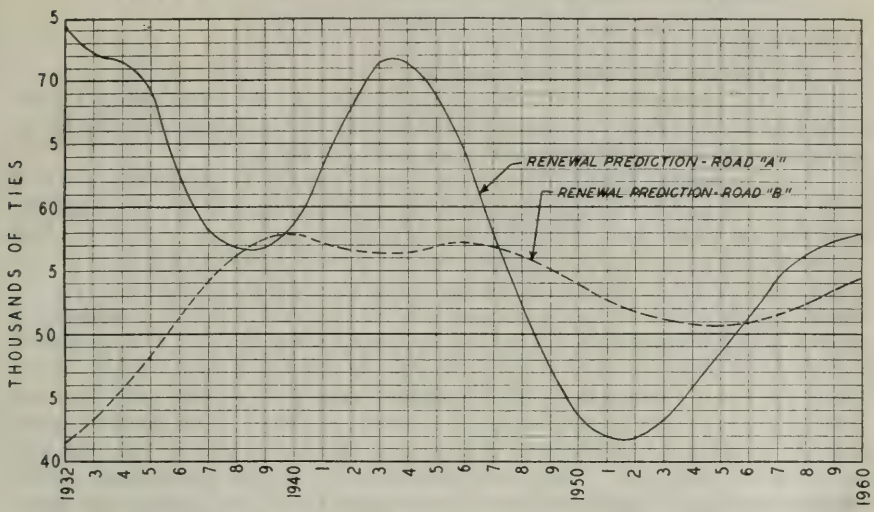


Fig. 4.—Illustration of predicted tie renewals on two roads having the same number of ties in track, Road B having started the use of the longer-life ties several years prior to Road A. This illustrates the fallacy of drawing conclusions from a comparison of tie renewals per mile, one road with another, without first ascertaining the normal renewal requirements of each road.

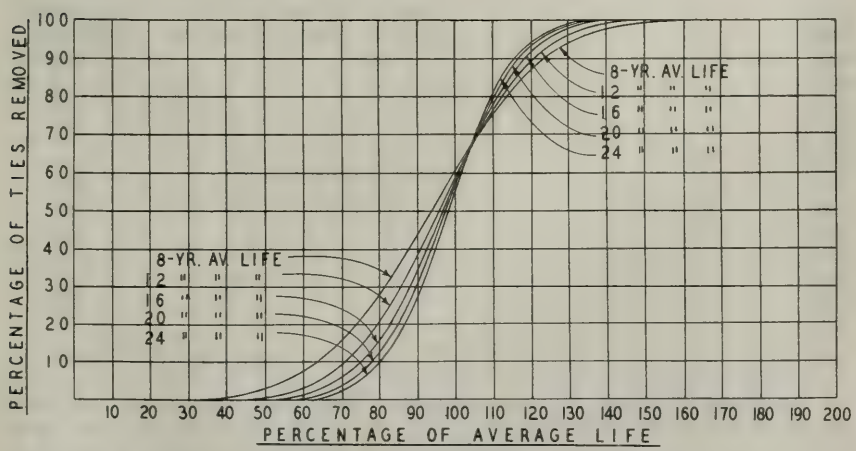


Fig. 5.—Comparison of selected renewal curves from Table 1, plotted in cumulative form.

PROCEDURE FOR MAKING PREDICTION BY USE OF TABLE 1

Data Required

(1) Year for which prediction is desired.

(2) The average life of each class of ties in track and the average life of the ties to be used in the future. (A method of determining the approximate average life of ties in track has been explained in another section of this report.)

(3) The number of ties of each class inserted annually in replacements and new work, prior to year for which prediction is made. Where track is old, the calculation must start far enough back of the first year of predicted renewals to make certain that all ties previously inserted which become due for renewal during the first year of predicted renewals will be included in the summation of renewals for that year. For example, if it is desired to start prediction with the year 1932, it is first necessary to determine what ties previously inserted will be renewed during that year. If the shortest average life of ties used was 7-years, by referring to Table 1, it will be found the last ties of the 7-year groups will be due for renewal during the 12th year after they were inserted. As far as the 7-year ties are concerned the calculation of the prediction starts with the ties inserted in 1920, and if there were no ties inserted prior to that time with an average life longer than 7 years, 1920 becomes the first year in the calculations of the complete prediction. The renewal rates as taken from Table 1 are applied to all groups of one class inserted prior to the first year of prediction.

Table 2 illustrates a form for tabulating the results obtained from the above calculations.

By the use of renewal rates in Table 1, applied to 143,811 ties with an average life of 7 years inserted in 1931 (as shown in Table 2), the predicted renewals of these ties would be as follows:

(1) *Year*	*(2)* *Years of Service*	*(3)* *Per cent of total inserted to be removed each year*	*(4)* *Number of ties to be removed each year*
1931	0	—	0
1932	1	—	0
1933	2	.3	431
1934	3	1.6	2301
1935	4	5.4	7766
1936	5	12.1	17401
1937	6	19.3	27756
1938	7	22.6	32501
1939	8	19.3	27756
1940	9	12.1	17401
1941	10	5.4	7766
1942	11	1.6	2301
1943	12	.3	431
1944	13	—	0
Total		100.0	143811

The figures in Column (3) were taken from Table 1 and represent the per cent of the 143,811 ties inserted during 1931 that are to be renewed during each year as shown in Column 1. The number of ties to be renewed each year as shown in Column 4 are then tabulated on a form similar to the one shown in Table 2. A separate tabulation must be made for each class of ties, and the summary of the tabulations by years will be the completed renewal prediction.

The graphic form of presenting the predictions as used in Fig. 1, 2, 3 and 4 is not necessary but it shows clearly the fluctuations in the renewals and can be used readily for making comparisons.

TABLE 1.—Percentage of total ties in group to be removed annually.

YEARS SERVICE (AGE)	ANNUAL RENEWAL RATES — AVERAGE LIFE																							
	7-YR	8-YR	9-YR	10-YR	11-YR	12-YR	13-YR	14-YR	15-YR	16-YR	17-YR	18-YR	19-YR	20-YR	21-YR	22-YR	23-YR	24-YR	25-YR	26-YR	27-YR	28-YR	29-YR	30-YR
1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2	.3	.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3	1.6	.6	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4	5.4	2.2	.8	.3	.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5	12.1	6.1	2.8	1.2	.5	.2	.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	19.3	12.2	6.7	3.3	1.5	.6	.2	.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7	22.6	18.3	12.2	7.1	3.7	1.8	.8	.3	.1	.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
8	19.3	21.0	17.5	12.1	7.4	4.1	2.1	1.0	.4	.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—
9	12.1	18.3	19.6	16.7	12.0	7.6	4.4	2.3	1.2	.5	.2	—	—	—	—	—	—	—	—	—	—	—	—	—
10	5.4	12.2	17.5	18.6	16.0	11.9	7.8	4.7	2.6	1.3	.7	.4	.2	.1	—	—	—	—	—	—	—	—	—	—
11	1.6	6.1	12.2	16.7	17.6	15.4	11.7	7.9	4.9	2.8	1.5	.8	.4	.2	.1	—	—	—	—	—	—	—	—	—
12	.3	2.2	6.7	12.1	16.0	16.8	14.9	11.5	8.0	5.1	3.0	1.7	.9	.4	.2	.1	—	—	—	—	—	—	—	—
13	—	.6	2.8	7.1	12.0	15.4	16.0	14.4	11.3	8.1	5.3	3.2	1.8	1.0	.5	.3	.1	.1	—	—	—	—	—	—
14	—	.1	.8	3.3	7.4	11.9	14.9	15.6	14.0	11.2	8.1	5.4	3.4	2.0	1.1	.5	.3	.1	.1	—	—	—	—	—
15	—	—	.2	1.2	3.7	7.6	11.7	14.4	15.0	13.5	11.0	8.1	5.5	3.5	2.1	1.2	.7	.3	.2	.1	—	—	—	—
16	—	—	—	.3	1.5	4.1	7.8	11.5	14.0	14.4	13.2	10.8	8.1	5.6	3.7	2.2	1.3	.7	.4	.2	.1	—	—	—
17	—	—	—	—	.5	1.8	4.4	7.9	11.3	13.5	14.0	12.8	10.6	8.1	5.7	3.8	2.4	1.4	.8	.4	.2	.1	—	—
18	—	—	—	—	.1	.6	2.1	4.7	8.0	11.2	13.2	13.6	12.5	10.5	8.1	5.8	3.9	2.5	1.5	.9	.5	.3	.1	.1
19	—	—	—	—	—	.2	.8	2.3	4.9	8.1	11.0	12.8	13.2	12.2	10.3	8.0	5.9	4.0	2.5	1.6	.9	.6	.3	.2
20	—	—	—	—	—	—	.2	1.0	2.6	5.1	8.1	10.8	12.5	12.8	11.9	10.2	8.0	5.9	4.1	2.7	1.7	1.0	.6	.3
21	—	—	—	—	—	—	.1	.3	1.2	2.8	5.3	8.1	10.6	12.2	12.5	11.7	10.0	8.0	6.0	4.2	2.8	1.8	1.1	.6
22	—	—	—	—	—	—	—	.1	.4	1.3	3.0	5.4	8.1	10.5	11.9	12.4	11.4	9.9	7.9	6.0	4.3	2.9	1.9	1.2
23	—	—	—	—	—	—	—	—	.1	.5	1.5	3.2	5.5	8.1	10.3	11.7	12.0	11.2	9.7	7.9	6.0	4.3	3.0	1.9
24	—	—	—	—	—	—	—	—	—	.2	.7	1.7	3.4	5.6	8.1	10.2	11.4	11.8	11.0	9.6	7.8	6.0	4.4	3.1
25	—	—	—	—	—	—	—	—	—	.1	.2	.8	1.8	3.5	5.7	8.0	10.0	11.2	11.4	10.8	9.5	7.8	6.0	4.5
26	—	—	—	—	—	—	—	—	—	—	—	.4	.9	2.0	3.7	5.8	8.0	9.9	11.0	11.2	10.7	9.4	7.8	6.0
27	—	—	—	—	—	—	—	—	—	—	—	—	.4	1.0	2.1	3.8	5.9	8.0	9.7	10.8	11.0	10.4	9.2	7.7
28	—	—	—	—	—	—	—	—	—	—	—	—	.2	.4	1.1	2.2	3.9	5.9	7.9	9.6	10.7	10.8	10.3	9.1
29	—	—	—	—	—	—	—	—	—	—	—	—	—	2	.5	1.2	2.4	4.0	6.0	7.9	9.5	10.4	10.6	10.1
30	—	—	—	—	—	—	—	—	—	—	—	—	—	.1	.2	.5	1.3	2.5	4.1	6.0	7.8	9.4	10.3	10.4
31	—	—	—	—	—	—	—	—	—	—	—	—	—	—	.1	.3	.7	1.4	2.6	4.2	6.0	7.8	9.2	10.1
32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	.1	.3	.7	1.5	2.7	4.3	6.0	7.8	9.1
33	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	.1	3	8	1.6	2.8	4.3	6.0	7.7
34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	.4	.9	1.7	2.9	4.4	6.0
35	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	.1	.2	.4	.9	1.8	3.0	4.5
36	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	.1	.2	.5	1.0	1.9	3.1
37	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	.1	.2	.6	1.1	1.9
38	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	.1	.3	.6	1.2
39	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	.1	.3	.6
40	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	.1	.3
41	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	.2
42	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	.1

METHOD OF DETERMINING APPROXIMATE AVERAGE LIFE OF TIES IN TRACK BY USE OF TABLE 3

Table 3, showing the percentage of ties remaining in track at the end of each year during the life spans of groups of ties producing average lives from 7 to 30 years, was calculated from the annual renewal rates shown in Fig. 1.

When records are not available to show what ties have been removed in making renewals in the past, it is not possible to compute the exact average life produced by each of the different classes of ties, but where data are available as to the number of each class of ties inserted each year, and the number of each class of ties in the track at the end of some year, the average life of each class can be estimated by a cut-and-try method, using Table 3.

In the early years of the life spans of ties the renewals are light and will probably vary considerably from the renewal curves shown in Table 1, until 10 per cent or more have been removed from the track. For this reason, the use of Table 3 should be limited to those groups in which 10 per cent or more of the ties inserted have been removed from the track.

The cut-and-try method of determining the estimated average life of ties in track when the only information available is the number inserted each year and the number remaining at the end of some year can best be explained by an example. On a road where there were 7,749,863 ties in track at the end of 1931, it was estimated that 43 per cent or 3,332,441 were zinc treated. Zinc treated ties had been used on this road during the years 1915 to 1928 inclusive, and the number inserted each year is shown in Column 2, Table 4. It was assumed that these ties produced an average life of 14 years, and on this basis the calculation shown in Table 4 was made to determine how many ties would remain in track at the end of 1931. The year 1931 would be the 16th year of service for ties inserted in 1915, and from Table 3, it is found that at the end of the 16th year 16.3 per cent of the 14-year ties remain in service. In the same manner the per cent remaining at the end of 1931 was taken from Table 3 and listed in Column 3 of Table 4, for all ties of this class inserted. It was found from Table 4, that the 14-year average life would have left a total of 3,590,654 ties in track at the end of 1931, and, therefore, the assumed average life was too long. Using an average life of 12 years 3,022,449 ties would have remained in track at the end of 1931, and with an average life of 13 years there would have been 3,341,907 ties in track. The latter figure is close to the number estimated to be in the track at the end of 1931, and the average life of 13 years was therefore used for making the renewal prediction. This same method was used for determining the average life of the untreated ties on this road, but as the use of creosoted ties was a fairly new practice only a small number had been removed at the end of 1931 so that it was necessary to estimate the average life of this class of ties on the basis of experience of other roads.

If records have been kept on test sections of track, the average life of the ties can be estimated for use in making renewal prediction of all ties of that class. Unless there are a large number of ties in the test sections, the cut-and-try method of determining the average life should be used as it takes into consideration all of the ties in track. The use of Table 3 for estimating the average life of ties in a test section, when 10 per cent or more have been removed, is explained in the following example. If in a group of ties 22 per cent have been removed at the end of 7 years of service, leaving 78 per cent in the track, it is found that in the line for 7-years service in Table 3, the figure 77.3 in the column headed 9-year average life is closest to the actual figure. The average life can therefore be assumed as 9 years.

TABLE 2.—Method of tabulating renewal prediction.

Untreated 7-year ties.

Year Inserted	*Number Inserted*	*1932*	*1933*	*1934*	*1935*	*1936*	*1937*	*1938*	*1939*	*1940*	*1941*	*1942*	*1943*
		Number of ties to be removed each year.											
1920	141000	423	0										
1921	148756	2380	446	0									
1922	151599	8186	2426	455	0								
1923	148453	17963	8016	2375	445	0							
1924	142904	27581	17291	7717	2286	429	0						
1925	138775	31362	26784	16792	7494	2220	416	0					
1926	138111	26656	31213	26656	16711	7458	2210	414	0				
1927	140404	16989	27098	31732	27098	16989	7582	2246	421	0			
1928	143532	7751	17367	27701	32438	27701	17367	7751	2297	431	0		
1929	145455	2327	7855	17600	28073	32873	28073	17600	7855	2327	436	0	
1930	145456	436	2327	7855	17600	28073	32874	28073	17600	7855	2327	436	0
1931	143811	0	431	2301	7766	17401	27756	32501	27756	17401	7766	2301	431
1932	142054		0	424									
1933	141254			0									
1934	141608												

A prediction of renewals of 7-year ties was used to illustrate the form of tabulation shown above. The number of ties to be renewed each year was found by applying the renewal rates for 7-year ties to the number of ties inserted as shown in the second column. The actual renewal figures were used in the second column for the years 1919 to 1931 inclusive. The total of renewals in column headed 1932, is the prediction of renewals for that year. The predicted renewals for 1932 is placed in second column and the renewal rates applied to this figure in the same manner as for the previous renewals in this column. This process is continued for the years subsequent to 1932 if the prediction is to cover more than one year. The prediction is completed in the above tabulation for the years 1932, 1933 and 1934.

TABLE 4.—Calculation made by use of Table 3, to determine the number of ties remaining in track at the end of 1931, using an average life of 14 years.

(1) *Year Inserted*	*(2)* *Number Inserted*	*(3)* *Per cent in Track at end of 1931*	*(4)* *Ties in Track at end of 1931*
1915	1,581	16.3	258
1916	26,090	27.8	7,253
1917	224,579	42.2	94,772
1918	181,399	57.8	104,849
1919	464,112	72.2	335,088
1920	531,638	83.7	444,981
1921	324,753	91.6	297,474
1922	533,732	96.3	513,579
1923	699,964	98.6	690,165
1924	604,854	99.6	602,435
1925	200,000	99.9	199,800
1926	100,000	100.0	100,000
1927	100,000	100.0	100,000
1928	100,000	100.0	100,000
			3,590,654

TABLE 3.—Percentage of ties in track at end of year.

YEARS SERVICE	PERCENTAGE OF TIES IN TRACK AT END OF YEAR																							
	AVERAGE LIFE																							
(AGE)	7-YR.	8-YR	9-YR	10-YR	11-YR	12-YR	13-YR	14-YR	15-YR	16-YR	17-YR	18-YR	19-YR	20-YR	21-YR	22-YR	23-YR	24-YR	25-YR	26-YR	27-YR	28-YR	29-YR	30-YR
1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2	99.7	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
3	98.1	99.3	99.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
4	92.7	97.1	99.0	99.7	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
5	80.6	91.0	96.2	98.5	99.4	99.8	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
6	61.3	78.8	89.5	95.2	97.9	99.2	99.7	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
7	38.7	60.5	77.3	88.1	94.2	97.4	98.9	99.6	99.9	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
8	19.4	39.5	59.8	76.0	86.8	93.3	96.8	98.6	99.5	99.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
9	7.3	21.2	40.2	59.3	74.8	85.7	92.4	96.3	98.3	99.2	99.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
10	1.9	9.0	22.7	40.7	58.8	73.8	84.6	91.6	95.7	97.9	99.1	99.6	99.8	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
11	.3	2.9	10.5	24.0	41.2	58.4	72.9	83.7	90.8	95.1	97.6	98.8	99.4	99.7	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
12	–	.7	3.8	11.9	25.2	41.6	58.0	72.2	82.8	90.0	94.6	97.1	98.5	99.3	99.7	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
13		.1	1.0	4.8	13.2	26.2	42.0	57.8	71.5	81.9	89.3	93.9	96.7	98.3	99.2	99.6	99.9	99.9	100.0	100.0	100.0	100.0	100.0	100.0
14		–	.2	1.5	5.8	14.3	27.1	42.2	57.5	70.7	81.2	88.5	93.3	96.3	98.1	99.1	99.6	99.8	99.9	100.0	100.0	100.0	100.0	100.0
15			–	.3	2.1	6.7	15.4	27.8	42.5	57.2	70.2	80.4	87.8	92.8	96.0	97.9	98.9	99.5	99.7	99.9	100.0	100.0	100.0	100.0
16				–	.6	2.6	7.6	16.3	28.5	42.8	57.0	69.6	79.7	87.2	92.3	95.7	97.6	98.8	99.3	99.7	99.9	100.0	100.0	100.0
17					.1	.8	3.2	8.4	17.2	29.3	43.0	56.8	69.1	79.1	86.6	91.9	95.2	97.4	98.5	99.3	99.7	99.9	100.0	100.0
18					–	.2	1.1	3.7	9.2	18.1	29.8	43.2	56.6	68.6	78.5	86.1	91.3	94.9	97.0	98.4	99.2	99.6	99.9	99.9
19						–	.3	1.4	4.3	10.0	18.8	30.4	43.4	56.4	68.2	78.1	85.4	90.9	94.4	96.8	98.3	99.0	99.6	99.7
20							.1	.4	1.7	4.9	10.7	19.6	30.9	43.6	56.3	67.9	77.4	85.0	90.3	94.1	96.6	98.0	99.0	99.4
21							–	.1	.5	2.1	5.4	11.5	20.3	31.4	43.7	56.2	67.4	77.0	84.3	89.9	93.8	96.2	97.9	98.8
22								–	.1	.8	2.4	6.1	12.2	20.9	31.8	43.8	56.0	67.1	76.4	83.9	89.5	93.3	96.0	97.6
23									–	.3	.9	2.9	6.7	12.8	21.5	32.1	44.0	55.9	66.7	76.0	83.5	89.0	93.0	95.7
24										.1	2	1.2	3.3	7.2	13.4	21.9	32.6	44.1	55.7	66.4	75.7	83.0	88.6	92.6
25										–	–	.4	1.5	3.7	7.7	13.9	22.6	32.9	44.3	55.6	66.2	75.2	82.6	88.1
26												–	.6	1.7	4.0	8.1	14.6	23.0	33.3	44.4	55.5	65.8	74.8	82.1
27													.2	.7	1.9	4.3	8.7	15.0	23.6	33.6	44.5	55.4	65.6	74.4
28													–	.3	.8	2.1	4.8	9.1	15.7	24.0	33.8	44.6	55.3	65.3
29														.1	3	.9	2.4	5.1	9.7	16.1	24.3	34.2	44.7	55.2
30														–	.1	.4	1.1	2.6	5.6	10.1	16.5	24.8	34.4	44.8
31															–	1	.4	1.2	3.0	5.9	10.5	17.0	25.2	34.7
32																–	.1	.5	1.5	3.2	6.2	11.0	17.4	25.6
33																	–	2	.7	1.6	3.4	6.7	11.4	17.9
34																		.1	.3	.7	1.7	3.8	7.0	11.9
35																		–	.1	.3	.8	2.0	4.0	7.4
36																			–	1	.3	1.0	2.1	4.3
37																				–	1	4	1.0	2.4
38																					–	1	4	1.2
39																						–	1	6
40																							–	3
41																								1
42																								–

Appendix G

(9) TYPE OF TIE PLATE BEST ADAPTED FOR USE WITH PRE-ADZED TIES

H. R. Clarke, Chairman, Sub-Committee; W. C. Bolin, R. E. Butler, Doyle Campbell, E. E. Chapman, L. O. Lower, L. T. Nuckols, L. J. Riegler, L. L. Tallyn, W. W. Wysor.

Since tie plates are placed on pre-adzed ties for the same purpose as on all other ties, that is, to prevent or reduce mechanical wear of ties and to strengthen the track structure, the same dimensions and data for designing tie plates should be followed in both cases (page 251, 1929 Manual). The only difference that might be justified is in the construction of the bottom of the plate.

Dr. A. N. Talbot, in report on "The desirability of reducing to a minimum the present variability factor in track" (Bulletin 346), has shown great variation in the stresses in the base of rail as measured at every other tie and has indicated the extent to which unequal tie support contributes to this.

Fairly comprehensive laboratory tests have indicated that a load considerably in excess of the usual wheel load is required to completely seat even a flat bottom two-rib plate in hardwood ties and a much greater load is required to seat plates having a more intricate bottom design. Rather extensive field observation has shown that in the case of plates with under side of various designs other than the flat bottom, two or three years' service is required to completely seat such plates. This condition results in looseness developing between the tie and the rail, as seating of the plate progresses. This condition was found by Dr. Talbot and tends to increase "the variability factor in track".

The plate bearing surfaces on pre-adzed ties are more uniform and more nearly in the same plane than if ties are not adzed. Therefore there is little need to provide for uneven initial bearing of the tie plate. It is desirable to use a plate which will be fully and completely seated as quickly as possible in order that the tie may be solidly tamped to a uniform and equal bearing. A flat bottom plate meets this requirement.

The Committee recommends a plate of adequate size and proper design to afford maximum protection from mechanical wear. If the plate is fastened to the tie independently of the rail fastening, the bottom should be flat and smooth. If the plate is not fastened to the tie independently of the rail fastening, the bottom should be flat with two shallow ribs at right angles to the length of the tie. These ribs are to increase resistance to lateral thrust and to assist in maintaining gage.

If plates with ribs are used, the Committee recommends the grooving for these ribs in connection with pre-adzing. This permits immediate seating of the plate and prevents cutting and breaking of the wood fibers after treatment. In order that pre-grooving may not complicate tie supply, the grooves should conform to a single standard location which shall be the same on all ties, the necessary accommodations for different rail sections to be made in the locations of the ribs on the bottoms of the tie plates. This recommendation is made with a knowledge of the facts that tie plates must be designed for given rail sections and must therefore be changed when rails of different section are laid and that properly protected creosoted ties will usually outlast one or even several changes of rail unless the ties are prematurely destroyed as the result of adzing or spiking at the times when rail is relaid. The single standard location for pre-cut grooves will materially lessen the necessity for adzing at the times when rail is relaid.

Appendix H

(10) ECONOMY OF USE OF TIE PLATES WHICH ARE SECURED TO THE TIE INDEPENDENTLY OF THE RAIL FASTENINGS, WITH PARTICULAR REFERENCE TO THE EFFECT ON TIE LIFE

W. C. Bolin, Chairman, Sub-Committee; R. E. Butler, Doyle Campbell, E. E. Chapman, H. R. Clarke, R. M. Jolley, L. O. Lower, L. T. Nuckols, L. J. Riegler, L. L. Tallyn, W. W. Wysor.

A comprehensive questionnaire was prepared and submitted to the railroads. Forty responded and of these twelve were able to report on the subject from actual experience. The response received indicated that this subject has been given serious consideration and a number of railroads have made quite heavy installations.

Independently fastened tie plates may be divided into two classes:

(a) Plates fastened to the tie independently of and in addition to the spikes which hold the rail down.

(b) Plates fastened to the tie independently of the rail fastening and with no spike bearing against the rail, the rail being fastened to the plate rather than to the tie.

Examples of both classes are usually larger than ordinary plates. Those of class (a) may have either single or double shoulders. Those of class (b) usually have double shoulders. Spikes used with class (a) are usually cut spikes or lag screws, though in some cases screw spikes are used. Screw spikes are used exclusively with class (b).

Most roads which have tried the tie plate which is secured to the tie by independent fastenings agree that there is an increase in tie life, an increase in rail life, and a decrease in the labor required for surfacing and regaging. The time in use has not been sufficient to determine the amount of these savings.

While there is some difference of opinion as to the effect on the labor cost of making tie renewals, it appears that this cost will not be affected materially.

The labor cost for relaying rail appears to vary with conditions: (a) Where rail can be renewed without disturbing the tie plates a saving is indicated; (b) where tie plates have to be reset or renewed, an increase in cost is indicated.

The second class of plate results in stiffer track and this permits lessened expansion allowance which, in turn, reacts to give lessened rail batter. The wave motion under trains is lessened and this reduces the ballast disturbance. In some types of class (b), rail renewal, of the same rail section, can be made without damage to the tie through respiking.

There is an increase in the cost for tie plates that are independently fastened. It has not been determined whether the saving resulting from increased rail and tie life and decreased maintenance labor is sufficient to warrant this expenditure.

Many roads report that the mechanical wear of the tie resulting from the cutting and abrasion effect of plates and tearing and splitting effect of spikes has been materially reduced, permitting the full benefit of the expense of tie treatment. However, the tie plates used with independent fastenings are larger and heavier than those used on the same class of track where independent fastenings are not used. We have not been able to determine to what extent this increase in size and weight, regardless of method of fastening, has had on the elimination of mechanical wear of ties.

The use of independently fastened plates has not been of sufficient extent or duration to permit conclusions as to the amount of the increase in tie life, although increased tie life is indicated.

Appendix I

(11) METHODS OF INSPECTION FOR RENEWAL OF TIES, CHECKING THEREOF AND ADHERENCE THERETO

R. S. Belcher, Chairman, Sub-Committee; H. F. Brown, S. B. Clement, R. L. Cook, E. L. Crugar, H. R. Duncan, C. F. Ford, C. W. Greene, R. M. Jolley, J. E. King, C. S. Kirkpatrick, F. C. Krell, S. E. Shoup, L. L. Tallyn, J. W. Tate, R. C. Young.

In order to develop information on this subject, your Committee last year sent out a questionnaire to members of the Association in an attempt to ascertain not only present practice of the several railroads, but also the opinion of those answering the questionnaire concerning present practice together with suggested changes and improvements. Replies were received from sixty-one roads having an aggregate mileage of approximately two hundred forty thousand miles. The Committee is very grateful for the hearty response to the questionnaire and the complete information and discussion given by those answering. The questionnaire appears on page 351 of Vol. 34 of the Proceedings.

Field Inspection to Determine Renewals Necessary

All roads reporting consider field inspection necessary as a basis for estimating the tie requirements for the following year. In general, this inspection is made in the fall of the year, but one road reporting not only makes this Fall inspection to determine the number of ties needing renewal during the following calendar year, but in addition, each month a portion of the territory is covered for the purpose of indicating to the section foreman those ties which will be renewed by him during each month.

On twenty-one of the roads reporting, this inspection is made by section foreman and roadmaster* together; on eighteen, by section foreman checked by roadmaster*; on eleven by roadmaster* only; six report that the section foreman makes the inspection alone, one reports that the section foreman makes the inspection supervised by an engineer, and one that the inspection is made by a special inspector.

On one road where the inspection is made by the section foreman and checked by the supervisor, a further inspection is made by the roadmaster of those locations where renewals appear unusual. On another road where inspection is made by the section foreman and roadmaster and checked by the Division Engineer, a further check is made by a maintenance inspector from the office of the Chief Engineer, sufficient to insure a conservative inspection. On another road both supervisor and assistant supervisor inspect with the section foreman, and on another road where inspection is made by the section foreman, a check is made by the roadmaster and Engineer of Maintenance of Way. On several roads where both section foreman and roadmaster make the inspection of important main track, inspection of back tracks and some of the branch lines is made by the section foreman alone, and only a general inspection and check of such tracks is made by the roadmaster.

It is evident from the information received that a great deal of importance is attached to this inspection of ties in track upon which the following year's tie renewals are based, and while there is considerable variation in the method used, yet practically all roads make some kind of a check of the original inspection. A few of the roads are of the opinion that something more than even the most careful inspection and check of same is well worth the time and effort required. One of these states that their present methods are the result of more than two years' field work by their general maintenance inspector who has conducted numerous meetings with their maintenance forces on the subject of economy of maintenance in its various phases and particularly in the use of

* Or Track Supervisor.

cross and switch ties for the proper maintenance of the railway, taking into consideration the class and density of traffic on the various lines. After these meetings, which are attended by the section foremen, track inspectors, roadmasters, Division Engineers and Engineers Maintenance of Way, it has been the practice to make a check of tie conditions on a convenient mile of track. After those in attendance have walked over this mile, all present make an estimate of ties requiring renewal in this mile. After comparing results, they return over the same mile, testing the condition of any of the ties which have been included in the estimate of those present, deciding whether or not they should be removed. The object of this is to impress on the foremen the necessity of making their decision on each questionable tie as it is at the time of inspection rather than as it may be six or eight months later. It has been found by this road that inflated estimates are generally the result of attempting to estimate the condition of the ties as they will be some months later.

After the meetings referred to, it is the practice to check at least one mile of each track section on each division by a group of five to six foremen, track inspector, roadmaster, and Division Engineer, and compare results with the original estimate. In all cases, the group agrees as to the actual requirements. The present plan of this road, of having section foremen prepare the original estimate, developed from a former plan of checking one or more miles on each section and applying the percentage of increase or decrease to the original estimate for the remainder of the section. This road believes they are now getting away from an arbitrary method of adjusting estimates. They feel that while all of this has taken a vast amount of time, yet thus far the results have more than justified the effort, because they are obtaining a more uniform and satisfactory distribution of renewals than formerly. They expect to continue the present system of checking tie conditions, and are of the opinion that their maintenance forces are very much more "Tie minded" than ever before.

As another illustration of the importance attached to the inspection of ties in track as a basis for renewals, another road concisely states their views on this subject as follows:

"The practice as outlined is that now in effect and is the method we have been following for the past several years. It is the result of a good deal of argument and discussion among ourselves and we think is the practice best adapted to secure the economical use of ties and at the same time keep the track tied up to the standard desired. Summed up, it is our opinion decision as to ties that are to be renewed should be made by the section foreman with very close and constant supervision by the roadmaster and continual checking by all other officers concerned with maintenance of way, as indicated, up to and including the Vice-President. Our experience has convinced us that it is not possible to make an inspection of ties in the fall which will correctly indicate those which should be renewed the following spring and summer, yet the inspection in the fall must be made as a basis of the tie allotment and for use in unloading and distributing ties as they are shipped out. Another advantage of this inspection is that it gives the roadmaster and the section foreman a very accurate idea of their track conditions, especially in regard to ties, just before they go into the winter.

"It is our belief that the tie allotment authorized should be held if possible somewhat below what we may think the real requirements will be, as we know that if the allotment is liberal and ties furnished accordingly, they will be used in the same way. Therefore, it is our practice to authorize an allotment which we think will be a little below the actual requirements and then increase this allotment as the working season progresses the following year as may be necessary, planning of course, to have the necessary ties in stock to enable these increases to be taken care of when authorized.

"It is our opinion the final inspection to determine renewals should be made as the work is being done, this inspection being made by the section foreman and if at all possible by the roadmaster or the track supervisor working with him. Where we have track supervisors, we require that they, with the section foreman, inspect all main track ties to be renewed before taken out. Where we do not have track supervisors, we expect the roadmaster to do this just as much as he can and hold him responsible for all ties taken out."

Marking Ties for Renewal

Seventeen of the sixty-one roads reporting do not mark the ties which are to be renewed. Of the remainder, sixteen chip off a corner or notch tie with axe or adze, nine of the roads spot the ties to be renewed with paint, eight place a spot of paint on web or base of rail directly over the tie to be renewed. White, yellow and red are the colors used and the practice of one road is to alternate each year between yellow and white. Two roads mark the ties to be renewed with crayon and six mark the rail with crayon or keel directly above the tie. Three roads mark the ties to be taken out with a branding hammer. One of these roads on first inspection brands the ties with a circle about one-inch in diameter on the top surface, line end, and on the second inspection, the ties are branded with a circle about one and one-half inches in diameter with the letter "R" inside that circle, which mark instructs the foreman to renew the tie. One road uses a vertical keel mark on the web of rail over the tie to be renewed. If reinspection of roadmaster and Engineer shows that the tie can be retained in service for another year, a cross line parallel with the rail is made through vertical keel mark of the section foreman, making the character "plus". One of the roads not now marking ties for renewal believes it is good practice to do so and hopes to start the system of marking next year.

Reporting Ties to be Renewed

Of the seventeen railroads which do not mark the ties to be removed at the time of inspection, one compiles results of inspection by mileposts and telegraph poles, nine by miles, and six by sections. One railroad reports the ties by five hundred-foot sections of main track, and yard tracks and sidings are reported as individual tracks. In general, whatever the unit used for reporting the number of ties needing renewal, this unit is separated as to tracks.

Railroads marking ties for renewal in general make as detailed an estimate as those that do not mark the ties to be renewed. Of the forty-four roads which mark the ties for replacement, two compile results by miles and telegraph poles, twenty-nine by miles, nine by sections and one by station stakes or mileposts. Three of the roads reporting ties for renewal by miles in main track report each side track as a unit. One road uses quarter-miles for main tracks and individual sidetracks and yard tracks; one road uses a unit of each five telegraph poles of each mile. In most cases, ties for renewals reported by telegraph poles, mileposts, quarter miles etc. are compiled to section, district and division totals.

Check of Original Field Inspection

The majority of roads reporting make a careful check of the original field inspection, although the methods used vary considerably. Twenty-eight of the roads report that the check is made by roadmasters, supervisors, or assistant supervisors and on twelve roads the Division Engineer makes the check. On one road the check is made by Division Engineer and a representative from the office of Chief Engineer Maintenance of Way; on another by the general roadmaster, on another by the general supervisor maintenance of way, on another by the superintendent maintenance of way and roadmaster; on two roads by the District Engineer Maintenance of Way, on another by the Division Engineer and general roadmaster; on two roads by the Division Engineer and roadmaster; and on one by the general track inspector, tie and timber agent and assistant engineer maintenance of way.

On one road the original inspection is made in the fall by the section foreman and roadmaster, and is check-inspected just before renewals in the spring by the same parties.

Two roads have special maintenance inspectors and the check of the original field inspection is made by inspecting ties at random on various sections, where renewals seem to be out of line. On one road special track inspectors are assigned to a part of the territory. On such territory, a detailed check is made of the foreman's estimate by the track inspector. After this has been completed, the roadmaster, accompanied by track inspector and section foreman, makes a recheck of such portions of the foreman's territory as may be necessary to satisfy himself that the count is correct. The Division Engineer is also required to make such check of estimates as may be necessary to enable him to assume full responsibility for them.

On one of the roads where the check is made by the District Engineer Maintenance of Way, such check is made only at points where recommendations for renewals seem excessive, but the record of field check as made by roadmaster and foreman is carefully checked in detail. The District Engineers are on the line practically all of the time and have a definite and accurate idea of tie conditions on their districts.

Likewise, on another road on which check of the original field inspection is made by the Division Engineer, sufficient territory is covered on each supervisor's district to enable the Division Engineer to know that the inspection for the whole division is made in a uniform manner.

Check of the original field inspection on another road is made by certain special maintenance inspectors, reporting to the office of Chief Engineer of Maintenance. These inspectors have previously made careful study of the renewals per mile over a period of years approximately equal to the average life of the ties to be renewed. The inspectors' observations of the records of the current inspection have indicated those locations where apparent irregularities in proposed renewals are evident. Insofar as the number of inspectors permit, they make reinspection of such miles. In addition, the reinspection of such locations is supplemented by requests to have the track supervisors reinspect those particular miles.

It is the practice on one road, on which roadmaster makes a check of the original inspection, that the roadmaster make a sufficient field check to satisfy himself so that he can assume the responsibility for the final recommendation on each mile of his section. On some sections it is necessary for the roadmaster to personally inspect every tie of the section foreman's recommendation; on others, the checking of a short distance is usually sufficient. Where roadmaster disagrees with section foreman's recommendation, he uses his own mark which is a vertical crayon mark on the rail above the tie in question so that if section foreman has put a horizontal mark on the rail, indicating that the tie is to come out and the roadmaster figures it should remain in track, he converts section foreman's horizontal mark into a cross by the use of his vertical mark.

Until about two years ago it was the practice on one of the railroads to not only have the original inspection of section foreman reviewed by track supervisor and afterwards by roadmaster or Division Engineer, but also to have an individual check made of part of each division by a visiting roadmaster, who would select from his list certain miles which seemed to require checking and make his report on those miles. In another case, where the original inspection is checked by Division Engineer, a general check of all divisions is made as the work progresses by the Engineer of Track and sufficiently by the Engineer Maintenance of Way to satisfy himself that the spotting is proper.

On one of the roads where the section foreman's field inspection is checked by the roadmaster and an Engineer for ordinary renewals, in cases where renewals are being made by ballasting or surfacing gangs, an inspector is usually kept with the gang constantly to mark the ties to be removed or to change the marking if this is shown to be necessary after the track is raised or ballast removed.

On one railroad where preliminary inspection is made during the early part of December by the roadmaster, the ties to be renewed are not actually blazed until a second inspection is made by the roadmaster which is usually made in January or February, at which time the roadmaster himself blazes the ties to be renewed. The preliminary inspection made in December is to enable a fairly accurate estimate of requirements for the ensuing year and it is generally found that the two estimates made by the roadmaster are not very far apart, and, as a general proposition, the number of ties actually blazed totals somewhat less than the estimated number.

While there is considerable diversity of methods used by the various roads as a check on the original inspection, it is quite evident from the study of replies to the questionnaire that the check of original inspection is considered of much importance, and while all roads do not reinspect all ties, a sufficient reinspection is made by some competent official to assure the accuracy of the original inspection.

Variation between Original Survey and the Check

The majority of those reporting have found that the number of ties estimated ready for replacement at the time of the original survey is greater than the total requiring renewal shown by the check. This difference is variously reported at five to twenty-five per cent. One road reports that some section foremen vary as much as forty per cent while others make very close estimates. Some roads report little variation between the original survey and the check. One states that usually the section foremen and roadmasters report a fewer number of renewals to be necessary than the Division Engineer finds to be the case. A few roads find there is considerable variation in both directions. The general experience seems to have been that as a rule the original survey made by foremen and roadmasters can be somewhat reduced but that this is not always the case and occasionally an increase is found to be necessary as a result of the second check.

One Chief Engineer points out that there is a tendency on the part of the section foreman to overstate his requirements in anticipation of an allotment which is less than that for which he is asking. Another Engineer notes that the tendency shown by the rechecks is to indicate decreases in requirements which of course show great variety and extremes per mile in individual cases. The majority of such rechecks, however, probably fall near the average decreases thus found as a result of the work on the system which, for the last year tabulated, indicated fifteen per cent. When the rechecks were first started on this road, it was found that for the system as a whole, the inspection developed a total for the system of renewals required thirty per cent in excess of the actual renewals made during that year. Five years later with the system of rechecking in effect, the per cent of inspection over actual renewals had been reduced to nine per cent. The method simply resulted in causing the original inspectors, the supervisors, gradually to more nearly exercise the same care and attention that was given by those who made the reinspection.

Another Chief Engineer calls attention to the fact that the check on his railroad indicates that now the sections are accurately marked for renewal at the time of the original survey, but this is due to the fact that this road has been spotting ties for nineteen years. Considerable educational work was required in the first years the present method was in effect. Another report states that section foremen are more careful and consistent in their first inspection because of knowing that a check would be made by the Supervisor.

Inconsistencies in Estimates for Different Territories Under Similar Condition of Tie Timber, Track and Traffic

The personal equation is the reason given most frequently for inconsistencies in tie renewal requirements as reported by section foreman, roadmaster, etc., for different terri-

tories under similar conditions of tie timber, track and traffic. Such inconsistencies as occur are in general explained by normal differences in judgment as to what is considered the proper standard of renewal under any set of circumstances, is the opinion given in one reply to this question, while another states the only inconsistencies found are such as would be expected to be found upon a study of human nature. These inconsistencies always exist but with constant attention by maintenance officers improvement may be made.

One maintenance official calls attention to the fact that the section foreman and roadmaster frequently call for fewer renewals on pieces of track which have been reballasted in recent years than are necessary to keep up current maintenance. This is believed to be partly due to reluctance to open up the new ballast any more than necessary. A very considerable number of the roads report that variations due to the personal equation are corrected to a large extent by the use of uniform instructions and by holding staff meetings, and by a long and continued process of education. Many inconsistencies or variations appear in the original survey which are adjusted in the following recheck. One road notes there is more variation apparent when ties of short life are being used than is the case where ties are either treated or are of a long life variety.

A portion of the roads report few inconsistencies in recommendations for renewals. A reason given for the uniform reporting is that methods and standards have been in effect for so long a time that officers and men are familiar with and capable of carrying out such methods with a fair degree of uniformity.

Methods Followed for Tie Allotments When Supply is Inadequate to Cover Amount Determined by Field Inspection

On some roads a sufficient supply of ties is kept on hand so that it is always possible to take care of requirements as determined by field inspection and check. From a road on which this is the condition comes the following reply:

"Ties are purchased on the basis of past requirements usually well over a year ahead of the time needed. For some years past at least, our stock of ties has been large enough to permit increasing the allotment, if, as the work progressed, this was found necessary. It is our policy to keep track in good safe condition for ties. If, as tie renewals progress, the allotment is found insufficient, an inspection is made by District Engineer Maintenance of Way, accompanied by the Division Superintendent and roadmaster. Additional ties are authorized on the recommendation of the District Engineer Maintenance of Way."

Another road reports that preference is given to appropriations for tie renewals and normal replacements are made each year. When necessary to reduce the maintenance budget sacrifice is made elsewhere and they are not, therefore, confronted with the problem of adjusting the tie allotments to curtailments in the authorized supply. Others secure authority for the purchase of additional ties.

The larger portion of the roads report some method for the allotment of the tie supply when this is less than the amount determined by field inspection and check. Various methods in effect on these roads are: Ties are used where most needed with a view to making safe operating conditions.

Important main lines are given preference. Minor tracks are assigned enough ties to make them safe for the service required.

Track being surfaced and curves are usually favored.

Preference is given to tracks carrying the heaviest tonnage.

In some cases where there is no great difference between the ties available and the number needed, the allotment is prorated.

On some roads allotments are made on the basis of reinspection.

As one Chief Engineer points out, this condition of insufficient tie supply usually comes in times of reduced traffic when a considerable number of yard tracks are not required and can be spiked or used as storage tracks, on which renewals will then not be necessary.

On many of the roads, it is the responsibility of the Division Engineer or other maintenance officer to adhere to the allotment and confine renewals to locations where most needed, curtailing replacements on the basis of his actual knowledge of the traffic, speed and condition of track in his territory, all of which is given consideration in making distribution of the ties. One road uses the following definite method:

"1. Allot sufficient main track ties to main line districts where traffic is greatest, to make it safe for one year.
2. Install about fifty per cent of the siding ties originally allotted.
3. Remainder of the total authorization of ties installed in main track, branch lines and main line districts where traffic is light."

One engineer states that "foremen are instructed to renew only broken ties or ties which are not holding the gage and which must be immediately renewed to keep the track safe. Data as to requirements is predicated upon check made by Roadmaster under the above rules."

On one road it is the practice to keep a careful record of locations where tie renewals have to be deferred or reduced on account of insufficient supply so that these may be given preference with the next allotment.

One Chief Engineer reports a horizontal and uniform reduction as follows:

"Tie allotments are based jointly upon a field inspection and the forecast of renewals for particular divisions, which latter are founded upon the report of tie service over a period of years past extending well beyond the average life of the ties to be renewed.

"To the extent that it is necessary to reduce allotments to meet authorities less than those indicated by the requirements as determined by the above method, it is done by horizontal and uniform reduction, with such modification as the particular immediate requirement in any locality may warrant."

Other roads report that unless there are conditions which require special consideration, the allotments are reduced proportionally. In some cases proration is applied to small units such as between telegraph poles, so that no locality will suffer unduly.

Detailed records of tie renewals have been found of value to show the relative urgency of renewals in different localities, supervisors' districts, etc. One Engineer states:

"Our detailed records of tie renewals during the past ten or twelve years, together with personal inspections of such locations where there may be any doubt as to the feasibility of making reductions, have enabled us to handle satisfactorily problems of supply curtailment."

Another states:

"Record is kept of the total number of ties in track and the number of actual renewals for years past by Supervisors' Districts. Past renewals are compared with the normal renewals on the basis of expected life and consideration is further given to the fact as to whether there are any stretches of road where the ties are beginning or ending a cycle of renewals".

Still another uses renewal records as follows:

"Usually the average renewals for the past five year period are compared with the theoretical renewals necessary to comply with our computed tie life and the limited supply is used as far as to maintain the average renewals indicated as necessary on this basis, but modified, based on judgment, to meet the obvious needs as shown by the inspection."

Importance of Inspection of Old Ties Taken out of Track

The importance attached to the inspection of old ties taken out of track as a check on extravagance in making tie renewals is indicated by the fact that all but one of the railroads answering the questionnaire make at least an inspection of a representative number of the ties taken out of track and many have inspection of all old ties made before they are removed from the right-of-way or destroyed. This inspection is made by Track Supervisors, Roadmaster, General Roadmaster, Division Engineers, or special inspectors, and in most cases other officers check such inspection from time to time. One Maintenance Officer reports that old ties are always inspected by the Roadmaster before they are destroyed and are frequently inspected by other officers up to and including the Vice President, and an Engineer Maintenance of Way reports:

"Our instructions call for all old ties taken out to be held on right-of-way for inspection by roadmaster before being burned or otherwise disposed of. General and division officers on inspection trips make it a point to examine all old ties and carry on educational campaign among Roadmasters and Foremen to avoid removal of ties before they have served their full life. We consider this of great importance and while complete uniformity of treatment by all foremen is not obtainable, more can be done to approach this ideal by examining with the foremen ties taken out of the track, than in any other way."

Another Engineer Maintenance of Way is also convinced of the importance of such inspection. He writes:

"Frequent inspection of track and old ties taken out of track is constantly followed up by officers concerned during the period tie renewals are being made, in order to avoid extravagant or inadequate renewals. This is the most important feature controlling the expense of tie renewals that there is. Nearly all foremen, including many of the best of them, having opened up the track to take out one or more ties in a place which obviously should be changed out are very likely to take out one or more adjacent ties which are still good for one or more years if left in the track, because they feel that, having already opened up the track, it would be a waste of money not to do so, or possibly because they do not like to fill in the crib and cover up a tie which is not in good condition even though it may be good for one or two years more life if undisturbed. It is this tendency of foremen which uses up a great many ties of their limited supply on one portion of their section, which then leaves them with fewer ties than are actually needed on the balance of their section. This, of course is good argument for the marking of ties by the inspector. The trouble there, however, is that the inspectors' judgment is not infallible, nor under the ordinary procedure can he make an adequate inspection of all ties in the track in order that there will be no error in the marking of all ties he reports as necessary for renewal. It is for this reason that we do not feel the practice of marking ties by the inspector is the best method to follow. It is felt, however, that mile for mile his judgment is sufficiently good so that the number of ties he reports as necessary for renewal will average up to about what is actually found necessary when the renewals are in progress."

A Chief Engineer writes:

"Ties taken out of track are piled on the right of way, and are inspected by the Assistant Superintendent and roadmaster before being burned or destroyed, in order to prevent extravagance in the use of new ties. In case any ties are found to have been removed from track, which do not show Roadmaster's blazing, the Section Foreman is required to explain in detail why the tie was removed contrary to instructions, and if satisfactory explanation cannot be given, the Section Foreman is severely disciplined."

Coincident with the inspection of old ties taken out of track, observations are made of the track by most of the roads to know that satisfactory conditions have been provided by the renewals made.

Several of the replies to the questionnaire call attention to the fact that greater care is used in the selection of ties for renewal because it is known that there will be an

inspection of the ties removed before they are destroyed or taken from the right-of-way. One Chief Engineer states:

"Section foremen are instructed not to dispose of old ties removed from track until they are inspected by the supervisor. The Division Engineer also makes regular inspections of ties removed, and the Chief Engineer gets on the ground two or three times during the season. The purpose of these inspections is to verify the judgment of the supervisors in marking ties for renewal. Experience has educated the supervisor, so that very few ties are marked that should not have been taken out. The inspections by the Division Engineer and Chief Engineer have a tendency to make the supervisors more careful in marking ties for renewal."

Another Chief Engineer whose road makes it the practice to inspect ties after they are taken out of track to avoid extravagance, states however:

"It is my experience that the tie allowance is the governing factor. The only way to avoid taking out good ties is to limit the allowance to absolute necessities and our entire tie allowance program is carried out on this theory."

The one road reporting no inspection of old ties is made, states that it has been the practice in the past to inspect old ties taken out of track but infrequent checks and the method followed in marking ties for renewal show a general check unnecessary. On this road Section foremen and track supervisor make independent field inspections and are checked by Division Engineer. The ties are not marked for renewal until after the allotment is fixed and prior to the renewal of the ties, when the Supervisor, accompanied by the Section Foreman, goes over the tracks and marks with keel all ties to be removed.

Latitude Allowed Section Foremen Renewing Ties at Variance with Yearly Maintenance Allotment

On the majority of railroads section foremen are not allowed to renew ties in excess of the yearly allotment. On a great many of the roads which do not allow the section foremen to exceed the allotment, if it is found that for one reason or another more ties are needed than provided for, the situation is called to the attention of the roadmaster or track supervisor and through him arrangements made for the additional ties needed.

On one of the roads where no latitude its allowed the section foremen in removing ties at variance with the yearly maintenance allotment, that allotment is arbitrarily increased 5 per cent above the number spotted over the division to compensate for errors of judgment and occasional renewals caused by derailments and other damage. Another road adds 10 per cent to the main line spotting to cover conditions as they appear in the Spring. In this case the ties are spotted in September and October, while renewals do not commence until the middle of April. On one road where the renewal program is based on reports of ties needed on each mile of main track and each siding separately, the section foremen are not allowed to deviate from the number of ties assigned each mile or siding, but if, due to changed conditions, it is the opinion of foremen and Roadmaster that additional ties are required, a reinspection is made and additional ties furnished if needed.

On one road on which foremen are not allowed to exceed the allotment for their section without authority, and this allotment of ties is based on inspection made in the Fall, actual renewal of ties is determined by a more careful examination at the time the work is being done, this examination being the governing factor. Roadmaster and Track Supervisors inspect a large percent of the ties with the section foreman before actual renewal is made, this inspection being carried along throughout the renewal season, keeping ahead of the work.

On a road where it is the practice for the Track Supervisor to make the field inspection to determine the renewals necessary, the section foremen are generally given the

allotment of ties for their section for the year, which are to be distributed per mile in proportion to the ratio established by the inspection. This distribution is not a hard and fast rule, the section foremen being required only in the event of finding it necessary to extend the renewals on one or more miles, to reduce them in equal number on other miles. If necessary to increase the total renewal for the section additional authority must be secured.

In practically all cases where section foremen are allowed no latitude otherwise, they are permitted to take out broken ties, and ties made unsafe by derailments. One road reports that each section is given a monthly allotment of ties and section foreman must not exceed this allotment without permission. If additional ties are requested, track supervisor makes a personal inspection to determine actual requirements and makes necessary adjustments in tie allotments.

About one-fourth of the roads reporting rely upon the judgment of the section foreman to a greater degree than indicated above. For instance, on one road the foremen are permitted to deviate from the program if bad ties are found which were not in evidence at the time of the original inspection. On another road the foremen may remove ties other than those marked by the track supervisor if he thinks necessary, but they are left beside the track and not destroyed until the supervisor has an opportunity to inspect them. On several roads the foremen are permitted to vary from the allotment only to the extent which may be necessary to keep the track in safe condition. One road states that the judgment of the section foreman is trusted pretty freely and they rarely find him wrong. On another road the section foreman is permitted to remove any tie that will not in his judgment last one year, whether such tie has been spotted for renewal or not.

On a road on which it is not the practice for the roadmaster or supervisor to spot the ties for renewal, the section foremen are permitted to use their own judgment but are watched very closely to see that ties are not removed that have service life in the original location under heavy traffic. On this road many treated ties are removed from main line high-speed track due to mechanical wear that renders them unsafe for such locations. All such ties are used again in minor sidings and give many years of additional service.

Another road considers the count of ties to be removed and the allotment by sections only as a guide, and it is the endeavor to avoid applying any pressure by general instructions to get in ties simply to accomplish renewal of the program allotment. On this road it is impressed upon the roadmaster and foremen that each renewal of a tie is a separate and distinct undertaking regardless of the allotment or program. In this connection it is pointed out by many that the best time to inspect the ties is after the track is jacked up, while inspection at the time the ties are spotted is necessarily less complete and ties which look good on first inspection may show imperfections after the track is raised.

Advantages and Disadvantages of Spotting Ties for Renewal

Marking ties for renewal is a practice having many advantages and few disadvantages is the opinion of a large majority of the engineers answering this question. That this practice is economical and educational is the opinion of most of those in favor of marking the ties which are to be renewed. At least the approximate number of ties to be renewed can be counted and their location be likewise determined beforehand. This, as stated by one engineer, permits ties to be distributed exactly in accordance with requirements, thereby saving handling and trucking. It also enables any officer who may desire to check any portion of the track in advance of renewals, to determine the extent and justification of the renewals.

When the spotting is done by the supervisor, or by the section foremen and checked by the supervisor or roadmaster, it places the responsibility on the supervisor or roadmaster instead of on the section foremen and results in more uniform practice for the entire railroad.

That a check of the actual condition of the ties, as well as the judgment of the supervisor or roadmaster, can be made by any supervisory officer on the ground, and that the moral effect of the marking of the ties for renewal is good, and more care is used by those marking the ties because it is known that a future inspection of the marked ties will be made, is the opinion of many.

In the opinion of several of the engineers reporting, marking of ties to be renewed enables a better programming of the renewals for the following year and a closer estimate of ties needed for replacements than can be made by any other method. One Chief Engineer lists the advantages of spotting ties for renewals as follows:

1. It eliminates guessing as to the condition of the ties in track and as to the number of renewals required.
2. It gives a definite record of the physical condition of the ties in the property.
3. Being the basis for the allotment, the record of required renewals per mile of track, enables definite distribution of ties to the exact location where needed and avoids cost of rehandling.
4. It provides a complete adequate record of maintenance requirements in respect to this one most expensive item of all Maintenance of Way and Structures expenditures.

About 10 per cent of the engineers reporting are of the opinion there is no advantage gained by marking ties to be renewed, and some feel the practice is an actual handicap to proper and economical maintenance. The reasons given are:

1. Ties are renewed because marked which are afterwards found serviceable for another year.
2. The additional expense of marking is not justified.
3. Marking is unnecessary because section foreman can be trusted to decide whether any given tie should come out or not.

It has been the observation of one officer that where cross ties are spotted for renewal there is a tendency to take out the tie even though a more careful examination of the tie after the track is jacked up may indicate that renewal is unnecessary. He is of the opinion that there is a tendency on the part of the section foremen to take the position that because the tie is marked, his responsibility in the matter has ended.

A Chief Engineer on whose road it is the practice to mark the ties to be renewed writes as follows:

"Most main track ties are installed in sections that are given a general raise of about 2 in. and thoroughly tamped. Many times ties that look reasonably good on top have to be renewed due to decay or other causes. The Foreman in charge should have the privilege of using good judgment in such cases, and not held down to ties that are only spotted."

One one of the roads on which it is the practice for the track supervisor to spot the ties to be renewed, carefully checked by his Division Engineer and the office of the Engineer Maintenance of Way, this practice, in the opinion of the Chief Engineer of that road, has resulted in a tie allotment which, when forwarded to the management, can be properly defended. He writes:

"On this road we started spotting ties in 1930. Our allotment for ties in 1929 was 960,000; in 1930, 731,000; in 1931, 624,000; and due to the very careful spotting and on account of financial conditions we were able to get along in 1932 with 223,000—our estimate for ties for 1933 being 495,000."

"It can be readily seen that savings due to proper spotting of ties have been considerable on this road. I feel that it would have been impossible to make this saving safely with the old method."

Another Chief Engineer is quoted as follows:

"We have spotted ties for nineteen years, sufficient to get supervisory force and section forces well acquainted with the procedure and results. When well understood and worked it should produce:

1. A good average, tie condition the entire length of each section, instead of a spotty condition.
2. Economy in renewals in that ties are not renewed which should remain and the reverse.
3. Permits the necessary planning of section work.

"I believe our organization would spot ties of their own volition as necessary to the proper accomplishment of their work."

Another Chief Engineer makes the point that spotting of ties for renewal by the track supervisor gives the supervisor a better knowledge of his tie conditions that he can obtain in any other way, and while, in addition, walking track for the spotting of ties, the Supervisor secures a more intimate knowledge of conditions on his District apart from the condition of his ties, than would otherwise be obtained.

Special Tie Inspectors

Only four of the roads use special Tie Inspectors in any way in connection with the renewal of ties. On one of these on which the original inspection is made by the Track Supervisors, Special Inspectors are used to make the check of the original inspection. When and as these Inspectors are available for the inspection of cross ties, they are accompanied on any one mile or section by the Division Engineer or Assistant Division Engineer, if available, as well as the track supervisors, and always by the section foreman. These Inspectors report to the Maintenance Engineer.

On the second road the Special Inspectors make the original inspection. Their inspection is checked by the Division Engineer, to whom they report. They are accompanied by the section foreman over their respective sections.

On the third road the roadmaster accompanied by the section foreman makes the original inspection. The District Engineer checks the roadmaster's inspection in the field on at least five representative miles of each roadmaster's territory. A statement of the number of ties needed is then prepared and sent to the Engineer Maintenance of Way. The number of ties shown on this statement is then checked in the field by a Special Inspector from the office of Engineer Maintenance of Way. From five to ten miles on each roadmaster's territory is so checked. The Special Inspector is accompanied over their respective territories by the roadmasters when making his check of their count.

On the fourth road Special Tie Inspectors are used to inspect a representative number of old ties taken out of track. A report is made of the ties inspected classifying as to causes of failure, kind of wood, kind of treatment, and ties found fit for further service in main or side track, if any. These Inspectors at times, upon request of Chief Engineer System or operating officials, inspect ties in track with a view to checking estimates of ties to be renewed in certain stretches of track where rail renewal is contemplated, or other cases where tie conditions appear unusual or ties have apparently not given the length of service expected. They are usually accompanied by roadmaster and section foreman. They report to the Manager Treating Plants and he in turn to the Chief Engineer System. Operating officials are furnished copies of reports.

Special inspectors are recruited from Assistant Division Engineers, general foremen, and engineering forces of the Maintenance Department; in general, from those employees of the railroads whose training and experience have been such that they are readily adapted to the particular class of work they are called upon to perform. One road reports that Inspectors have been trained to secure uniform and satisfactory inspection by

working jointly on identical stretches of track, or with officers to whom they report, until the standard in respect to ties to be left in track is established.

The question was asked:

"What difficulties, if any, do you find in reconciling differences in judgment as to tie renewals between Special Inspectors and section foremen who are responsible for the safety of track?"

An Engineer on whose road Special Inspectors are used states:

"There are usually differences of opinion as between Special Inspectors and section foremen as to certain of the ties marked for renewal, these ties being of the character that might be termed marginal. There have been no differences that have not been reconcilable. Usually the Special Inspector with the prestige of the knowledge of the management's policy and standard of maintenance required has been able to show the foreman every practical advantage of the acceptance of the reinspections."

The Chief Engineer of a road on which special inspectors are not used expresses the opinion that there should be no trouble in reconciling differences in judgment as to tie renewals between a competent special inspector and a competent section foreman. A tie that will not hold the rail to surface and gage should be spotted for renewal, and a tie in this condition is easily determined. The standard of maintenance determined by the speed of trains and character of traffic is one to be determined by the maintenance officers and see that it is adhered to by the section foremen.

Representatives of some of the roads not only state that special inspectors are not used on their railroad but they do not think they should be used. A Chief Engineer states:

"The roadmaster is charged with the responsibility of keeping up his track and when he goes over the division on foot, as we require him to do, he finds many things he did not know about before and corrects them. It takes as high as two months for one of our roadmasters to cover his division, but I am absolutely certain that it is the best system yet devised to secure orderly renewal of ties with the minimum outlay of money."

Another feels that it is not good practice to relieve section foreman and district roadmaster of the responsibility of marking ties for renewal. Another is of the opinion that the man on the job in charge of a particular territory is better qualified to judge the requirements because of his knowledge of actual conditions and traffic, rather than any special inspector who may be entirely unfamiliar with the conditions of a certain section or district.

Those using special tie inspectors find a number of decided advantages when special inspectors are employed as they use them. One official on whose road special inspectors are used sums up the advantages of this practice very concisely as follows:

(a) By contacting supervisors or others who make the original tie inspections, the special tie inspectors are able to establish a more uniform character of tie inspection throughout.
(b) Their inspection of old ties removed has similar effect in respect to uniformity of renewals.
(c) Their association with division officers in connection with inspections and with renewals, even though but periodical, gradually leads to acceptance and application of the economic policy, which the management desires followed in connection with the use of ties.

A number of Engineers on whose roads special inspectors are not used, express the opinion that the use of special inspectors is not good practice because they cannot be familiar with local conditions and are not usually responsible for unsafe or bad riding conditions of the track. They feel that the roadmaster, or track supervisor, and the section foremen are the men responsible for track and therefore they should have the authority and be responsible for handling tie renewals.

The Use of Statistics as an Aid to the Determination of Tie Renewals

Statistics are not used *exclusively* for the determination of tie renewals by any road answering the questionnaire, although the large majority use statistics as a check on tie renewal estimates resulting from field inspection and as a guide to the trend of future renewals. All roads report that they consider field inspection necessary as a basis for the estimation of tie requirements for the following year, but there is a great difference in the extent to which statistics are used by the several roads. In fact, a few roads make no use of tie statistics whatever so far as determination of renewals is concerned, while on other roads these play an important part in the determination of the quantity and distribution of tie requirements.

Perhaps the opinion of the greater number of those answering the questionnaire is that expressed by one Chief Engineer as follows:

"Statistics are used as a matter of comparison of tie renewals from year to year. They are a helpful guide in determining whether or not the number of ties reported for renewal is correct. They are also very helpful in determining the average length of life of the ties so that more accurate estimates can be made of future maintenance expenditures."

A considerable number of the roads have records of tie renewals for many years back and from these know what the normal renewals should be. In lean operating years when tie allotments are below normal, the Divisions adjust their renewals accordingly. If estimated requirements for any mile, section or division are much in excess of the requirements indicated by the statistics, that particular mileage is checked by most of the roads to ascertain the discrepancy. One Engineer states:

"Recommendations for allotment are checked, by subdivisions, with tie renewals over a period of years, so that the trend of renewals may be noted. This check is not a governing factor, but is used by the Engineer Maintenance of Way to keep in touch with the developments that may be occurring."

Another Engineer reports that accurate statistics are kept by his road of tie renewals by years and these statistics are used to determine the average life of the various kinds of ties. From this average life of ties and the total number of ties in track, a reasonable figure for tie renewals per year is determined. This figure is used as a check against the requests of Section Foremen and Supervisors.

A railroad on which it is the practice to have the original field inspection made by the Track Supervisors and this inspection checked by Special Inspectors, also makes extensive use of tie statistics. This road reports:

"Statistics for the determination of tie renewal requirements are tabulated for main track ties for each of the respective divisions of the System. The average life of treated main track ties and the average life of untreated main track ties is fixed by test records and by experience. The statistics for each division are carried back over a period of years extending well beyond the average life. From such a base, using a curve of rate of renewals (approximately that shown by the experience curve of the Forest Products Laboratory), it is readily possible to compute the renewals required for the current year and the succeeding years.

"The advantages of the use of statistics for such purposes are self-evident. There is nothing more certain than the average life of a group of ties having similar characteristics. Such grouping needs to be no more refined than a separation between treated and untreated ties in order to give practical and accurate results in calculation of required renewals.

"No adjustments for abnormal conditions are required in connection with the use of sitatistics. It first is necessary only to determine the kind of ties, treated or untreated, and the year they went into track in order to predict through the use of the adopted tie renewal curve with absolute certainty the renewal requirements for each subsequent year. With such a record available as a base, it would not matter whether the line was newly constructed or not."

Other roads have worked out curves from past renewal statistics, from which, it is reported, it is possible to forecast the approximate number of ties needed to maintain the railroad for a number of years to come. Many of the roads keep these tie records by Division, and a few by smaller units. An Engineer who uses statistics covering renewals of past years as being of value for determining system requirements and percentages of the System allowance for distribution as between division, states:

"In determination of distribution on the Division, actual facts and knowledge of conditions are of first importance. If statistics where maintained in such a way as to give a record of renewals for each mile of main track and separately for each siding, over a period of years, analysis of same might point to apparent inconsistencies which would justify special investigation, but ordinarily statistics are not mantained in sufficient detail to be of value for such purposes."

An Engineer on whose road statistics are used in the determination of total tie renewals required on System Lines writes:

"The average life for each class of tie has been determined by study of application in renewals extending over thirty years and is used in conjunction with the tie curve of the Forest Products Laboratory to project future requirements. Statistics of tie renewals on each roadmaster's district are further used as a check on apportionment between districts."

During the transition period on a railroad changing from untreated to treated ties, the use of statistics is more difficult. An Engineer on whose road the use of treated ties was begun in 1921, gradually increasing the number used annually until about 1926, when the use of untreated ties was discontinued, writes:

"At this writing we have approximately 70 per cent of all ties in service treated and, consequently, the use of statistics for determining renewals cannot be accurately relied upon, but we anticipate that when our tracks have been entirely renewed with treated ties, we will be able to rely to some extent upon statistics for determining, approximately, at least, our future tie renewals. We are of course keeping an accurate record of removal of treated cross-ties for the different causes."

In short, to quote the opinion of one Engineer, which is typical of the opinion of a very considerable number, statistics do furnish a very reliable check, but statistics alone would not suffice because they make no allowance for local conditions nor variation in quality or life of ties, or the human equation.

Conditions which affect tie renewals and which place statistics at a disadvantage for the forecasting or check of renewals, are listed by one Engineer as follows:

(a) That at some time a large mileage might be retied with inferior wood which would come out much earlier than statistics would indicate.
(b) Occasionally many miles of new track or siding may be added in one year and eventually more ties will be needed for such divisions than statistics will show.
(c) The tonnage or speed of trains may be changed on a division and this would require a greater or less number of ties per mile than statistics would indicate.

However, a number of the roads adjust statistics for abnormal conditions especially with reference to newly constructed lines. A Chief Engineer writes:

"We have developed statistical data showing the proportion of ties that it is anticipated will require to be renewed each year on newly constructed lines. Statistics can be used to good advantage in allotting ties to relatively large units of track. On the smaller units such as the average track section, the "diversity factor" is not large enough to enable statistical control to be used without field inspection."

Another states:

"Our statistics are based on ties used in actual replacement. Ties in newly constructed lines enter into our calculations only in the number of ties in track."

Some roads using statistics built up on the basis of long periods of time as general averages only, adjust for abnormal conditions on the basis of judgment and a comparison of experience on similar districts for similar conditions. Relative to the adjustment of its tie graph for new lines, one road reports as follows:

"In determining the average number of ties per mile used in renewals each year, a correction is applied in cases where new lines have been constructed so that the averages derived furnish a comparison of the renewals on all districts, regardless of the date the lines were constructed—that is, the mileage of new track is not added in a lump the year the line is built but is spread over a fixed period of years in amounts proportionate to estimated tie renewals required for each year. For years prior to 1923, the following per cents were used in determining the mileage to be added:

At the end of the	first year	0	per cent
"	second year	0	"
"	third year	2	"
"	fourth year	3	"
"	fifth year	5	"
"	sixth year	5	"
"	seventh year	25	"
"	eighth year	50	"
"	ninth year	10	"

"After the ninth year no correction was applied, it being assumed that the new track then required renewals equally with the older tracks.

"In nearly all of our tracks constructed since 1922, creosoted ties have been used; therefore, commencing with the year 1923, the following per cents are used in determining the miles to be added:

At the end of the	first year	0	per cent
"	second year	0	"
"	third year	0	"
"	fourth year	1	"
"	fifth year	1	"
"	sixth year	1	"
"	seventh year	3	"
"	eighth year	5	"
"	ninth year	7	"
"	tenth year	8	"
"	eleventh year	9	"
"	twelfth year	10	"
"	thirteenth year	20	"
"	fourteenth year	25	"
"	fifteenth year	10	"

"After the fifteenth year, no correction is applied, it being assumed that the new track will then require renewals equally with the older tracks."

On the charts of another road the total mileage of newly constructed lines is not shown until the end of the tenth year. The precentages added to the total mileage at the end of each year on this road are as follows:

At the end of the	first year	0	per cent
"	second year	0	"
"	third year	2	"
"	fourth year	3	"
"	fifth year	5	"
"	sixth year	5	"
"	seventh year	20	"
"	eighth year	35	"
"	ninth year	20	"
"	tenth year	10	"

That the use of statistics as a check on renewal estimates resulting from field inspection, and as a forecast of future renewals, results in tie economies is the opinion of the roads who use statistics in this manner. The reasons given for this fact are as follows:

The Inspector in the field, knowing that his figures will be checked, is naturally more careful in the figures he reports as he knows he will have to substantiate any figures he reports.

The intelligent use of records and statistics is worth a great deal in the selection of ties adapted to the locality in which they are to be used and the traffic they bear. By this method it is possible to arrive at the most economical methods of treatment.

The use of statistics enables the supervising official to keep in touch with the situation and developments that may be occurring.

Statistics are used as a means of controlling maintenance expenditures.

The use of statistics provides a check on renewal requirements which cannot be obtained in any other way and show where investigation is necessary, thereby preventing waste and thus proving their use has an economical value.

Conclusions

In the foregoing your Committee has endeavored to consolidate the information, furnished by Engineers representing sixty-one railroads in response to the questionnaire, into a story of the methods used for the determination of annual tie renewals, expressions of opinion relative to the use of these methods and possible improvement in them. In this connection your Committee wishes to express its appreciation to those answering the questionnaire, not only for the hearty response but also for the complete yet concise manner in which each phase of the subject was covered.

On these sixty-one railroads, located in all parts of the country, it is to be expected that there is a wide range of conditions which affect methods used for the determination of annual tie requirements. Probably no one method satisfactory for use under all the conditions which obtain can be established. However, your Committee is of the opinion that under most conditions the following general methods will bring about safe and economical control of tie renewals:

1. Field inspection is necessary as a basis for estimating the replacements needed. A field inspection should be made at least once each year, preferably in the Fall. This inspection should be made by roadmaster or track supervisors accompanied by the section foreman, or by the section foreman and checked by the roadmaster or track supervisors, or others directly in charge of and responsible for the safety of the track. Additional check from time to time by other Maintenance officials is very desirable.

2. Ties found on inspection to require replacement should be spotted or branded to so indicate. If on reinspection ties marked for renewal are found which may be retained in service for another year, an additional mark of a different kind may be used to indicate this fact.

3. Ties to be renewed should be reported by some convenient unit such as miles and telegraph poles; miles; miles in main track and individual sidings or yard tracks; sections. Such reporting is an aid to the proper distribution of new ties and indicates localities where reinspection is desirable.

4. Information furnished the Committee indicates that *as a rule* the total number of ties estimated ready for replacement at the time of the original survey is greater than the total requiring renewal shown by the check, and original estimates are usually reduced accordingly. While there is a considerable diversity in the methods used it is quite evident that a check of the original field inspection, by one method or another, is essential to the safe and economical control of tie renewals.

5. If possible a sufficient supply of ties to meet requirements determined by field inspection and check should be kept on hand. When the tie supply is less than the

amount determined by field inspection and check, allotments should be made so that the ties available will be used where needed to make safe operating conditions and where they may be used to best advantage in the judgment of the maintenance officer responsible. A number of methods of allotment have been described in the foregoing.

6. Inspection of a representative number of old ties taken out of track should be made as a check on extravagance in making tie renewals and to ascertain causes of failure of ties of various kinds of woods and treatments. Such inspection should not only be made currently by the track supervisors or roadmaster, but also from time to time by Division and Maintenance Officers or Special Inspectors. It is believed more can be accomplished toward obtaining uniformity of judgment by all foremen, by examining with them ties taken out of track, than in any other way.

7. Section foremen should not be permitted to remove ties in excess of the yearly allotment. Should more ties be needed, in the opinion of the section foreman, than provided by the allotment, the situation should be called to the attention of the roadmaster or track supervisor, and through him authority obtained for the additional ties. Section foremen should be allowed some latitude in the removal of ties at variance with the marking for renewal, to provide for the replacement of ties broken, or otherwise injured so as to destroy their usefulness. Further deviation from the spotting may be found necessary throughout the renewal season as the ties are uncovered, but such deviation should be authorized from time to time by the roadmaster or track supervisor who should inspect a considerable per cent of the ties with the section foreman before actual renewal is made.

8. Special Inspectors chosen for their knowledge and experience instructed in the management's policy and the standard of maintenance required, may be used with resulting uniformity of practice. Such Inspectors are successfully used under certain plans of field inspection and estimation of tie requirements. Specially trained Inspectors may be used to advantage for the inspection of a representative number of old ties taken out of track, as a check on extravagant renewals and for the collection of data as to the causes of failure of ties of various treatments and kinds of wood. Special Inspectors may also be used for the annual check of tie test track.

9. Tie service statistics should not be used in lieu of field inspection but are of real value as a check on the renewal estimates resulting from field inspection and as a guide to the trend of future renewals. From detailed statistics average service life of ties of various kinds and treatments may be calculated. The proper use of statistics should result in efficiency and economy in the renewal practice.

REPORT OF COMMITTEE IV—RAIL

Earl Stimson, *Chairman;*
J. E. Armstrong,
W. J. Backes,
J. B. Baker,
W. C. Barnes,
F. L. C. Bond,
N. J. Boughton,
C. B. Bronson,
E. E. Chapman,
C. T. Dike,
W. A. Duff,
R. Faries,
J. M. Farrin,
L. C. Fritch,
F. W. Gardiner,
F. M. Graham,
C. R. Harding,
G. W. Harris,
B. Herman,
C. W. Johns,
J. E. King,
W. H. Kirkbride,
H. C. Mann,
Wm. Michel,
J. V. Neubert,
E. E. Oviatt,
W. H. Penfield,
W. H. Petersen,
A. F. Blaess, *Vice-Chairman;*
G. A. Phillips,
G. J. Ray,
A. N. Reece,
R. T. Scholes,
H. R. Thomas,
C. P. Van Gundy,
J. R. Watt,
C. E. Weaver,
J. E. Willoughby,
W. P. Wiltsee,
L. Yager,
J. B. Young,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully presents herewith its report covering the following assignments:

1. Revision of Manual (Appendix A).

2. Further research, including details of mill practice and manufacture as they affect rail quality and rail failures, giving special attention to transverse fissure failures, collaborating with the Rail Manufacturers' Technical Committee (Appendix B).

3. Compilation of statistics of all rail failures, making special study of transverse fissure failures (Appendices C, D and E).

4. Cause and prevention of rail battering, collaborating with Committee V—Track (Appendix F).

5. Economic value of different sizes of rail (Appendix G).

6. Rail lengths in excess of thirty-nine feet (Appendix H).

7. Information on tests of alloy and heat-treated carbon steel rail (Appendix I).

8. Redesign rail sections heavier than 100-lb. per yard so as to obtain the most economical distribution of metal with the maximum strength of section (Appendix J).

9. Heat treating of rail ends to reduce wear (Appendix F).

10. Design joint bars for RE rail sections as developed (Appendix K).

Action Recommended

1. That the revisions and additions to the Manual recommended in Appendix A be approved for publication in the Manual as recommended practice.

2. That progress reports on subjects 2 to 10 inclusive in Appendices B to K be received as information and that these subjects be continued with the exception of No. 6—"Rail Lengths in Excess of 39 Feet" which it is recommended be discontinued for the present.

Respectfully submitted,

The Committee on Rail,
Earl Stimson, *Chairman.*

Bulletin 363, January, 1934.

Appendix A

(1) REVISION OF MANUAL

A. F. Blaess, Chairman, Sub-Committee; W. C. Barnes, N. J. Boughton, C. B. Bronson, E. E. Chapman, W. A. Duff, L. C. Fritch, F. M. Graham, C. R. Harding, G. W. Harris, W. H. Penfield, G. J. Ray, C. P. VanGundy, W. P. Wiltsee, J. B. Young.

DEFINITIONS

The following changes and additions beginning at page 135 of the Manual, are recommended:

Add note after definition for Alloy Steel:

"The above definitions for iron and steel apply to joint bars, bolts and spring washers as well as rail."

Insert in alphabetical order under heading Manufacture:

Cobble.—"In a rolling mill, any steel which has become bent or twisted so that it cannot be finished by rolling is termed a "COBBLE".

Hotbed.—"A series of skids on which rails are placed for cooling after rolling, cambering and sawing."

Substitute—

Crop End.—"A piece cut from the end of a bloom or rail during manufacture."

Remove the word "with" in definition of Compound Fissure, line 2, page 16 of 1932 Supplement to Manual, Bulletin 347.

RAIL SPECIFICATIONS

The following corrections or changes are recommended:

Section 6, page 149: A request having been received for height of drop to be used in applying drop test to 70–80-lb. rail the following addition is recommended:

"For 70–80-lb. rail inclusive.....17 ft."

Section 12, page 150: Add "or drawings" after word "templets" in line 2.

Substitute: "width" for word "length", line 4.

Section 20 C, page 152: In order to avoid payment for weight in excess of the one-half of one per cent overrun allowed in Section 13, it is recommended that the words "subject to limitation of Section 13" be added making this sub-section read—

"Rail accepted will be paid for according to actual weight subject to the limitations of Section 13."

DRILLING OF RAILS

The following corrections or changes are recommended:

(1) Paragraph 1, page 162: Elimination of this general recommendation as unnecessary and inadvisable, as specific directions for drilling are elsewhere given. This includes the necessary renumbering of the succeeding paragraphs.

(2) Page 162: Revise data under heading "Application of Recommended Rail Drilling to Standard Rail Sections," to include only the present standard sections, as follows:

Weight of Rail, Lb.	*Type of Rail*	*Height of Bolt Hole Above Base of Rail, Inches*
90	RA–A	2 37/64
100	RE	2 45/64
112	RE	2 7/8
131	RE	3 3/32

This eliminates sections which are no longer standard and adds data for the 112-lb. and 131-lb. RE sections.

(3) Page 162: Revise the sentence, "The standard drilling for rails should be as shown in the following diagrams" to read, "The standard drilling for standard rails up to and including 100-lb. per yard should be as shown in the following diagrams".

SPECIFICATIONS FOR HIGH CARBON STEEL AND FOR QUENCHED CARBON STEEL JOINT BARS

(1929 Manual, pages 166–169)

In order to keep the same terms in all Rail Committee specifications, substitution of the word "heat" for "melt" wherever the latter is used is recommended.

While title of these specifications refers to Joint Bars there are a number of references to splice bars on page 169. Recommend uniform use of the term "Joint Bars."

Paragraph 13, page 169, last line: Recommend quenching temperature be shown in degrees Fahr. and degrees Centigrade enclosed in parentheses.

REVISION OF FORM 402 A

Following changes are recommended, pages 180–181 of Manual: Face of form, item 38—Change "Horizontal Fissure" to "Horizontal Split Head."

Back of form—Under "Description of Rail Failures", add new definition 1 B as given on page 16, Bulletin 347: (B) "Compound Fissure—A horizontal split head which in developing extends into a plane other than horizontal".

Designate definition for "Ordinary Break" by (C) instead of (B) and in third line of same substitute word "compound" for word "horizontal".

4. "Split Head"—Change title to "Vertical Split Head".

Add a new definition 5 as given on page 16, Bulletin 347: "Horizontal Split Head"—"A horizontal progressive fracture originating in the interior of the head of rail usually indicated on the side of head by longitudinal seam or crack and flow of metal".

Renumber definitions 5, 6 and 7 as 6, 7 and 8.

Eliminate the word "Internal" under the cut of "Internal Transverse Fissure".

Recommendations

1. That the changes and additions recommended above under heading "Definitions" be approved for publication in the Manual.

2. That the corrections or changes recommended above under heading "Rail Specifications" be approved for publication in the Manual.

3. That the corrections or changes recommended above under heading "Drilling of Rails" be approved for publication in the Manual.

4. That the revisions recommended above under heading "Specifications for High Carbon Steel and for Quenched Carbon Steel Joint Bars" be approved for publication in the Manual.

5. That the revision of Form 402–A—Report of Rail Failure in Main Track, recommended above under heading "Revision of Form 402–A" be approved for publication in the Manual.

A

Appendix B

(2) FURTHER RESEARCH, INCLUDING DETAILS OF MILL PRACTICE AND MANUFACTURE AS THEY AFFECT RAIL QUALITY AND RAIL FAILURES, GIVING SPECIAL ATTENTION TO TRANSVERSE FISSURE FAILURES, COLLABORATING WITH RAIL MANUFACTURERS' TECHNICAL COMMITTEE

Earl Stimson, Chairman, Sub-Committee; A. F. Blaess, W. C. Barnes, C. B. Bronson, E. E. Chapman, R. Faries, J. V. Neubert, G. J. Ray, W. P. Wiltsee, L. Yager.

For a general outline or program of the Joint Investigation, being carried on at the University of Illinois by the Rail Committee and by the Rail Manufacturers' Technical Committee to determine the cause of and remedy for transverse fissure and other rail failures, reference is made to the Committee's report to the March 1932 Convention (A.R.E.A. Proceedings 1932, Vol. 33, pages 557–8).

This investigation is now in its third year and definite progress is being made. The laboratory work is continuing but greater emphasis is now being placed on the second stage of the investigation, namely, the field tests of rails that were placed in service on the B.&O. and A.T.&S.F. Special equipment has been obtained for the intensive study of the behavior of these rails in service and for the recording of the service stresses to which they are subjected. This work will be followed by a correlation of the laboratory and field test results.

These tests are for the purpose of, first, determining the presence of any transverse fissure developments in the rails and, second, measuring the magnitude of the wheel loads which are actually met in service. The tests for transverse fissures are made by the drop-of-potential method, using apparatus mounted on a car specially designed and constructed for these tests. A scratch extensometer was developed by members of the research staff to measure the elongation of the base of the rail under moving trains from which the wheel loads are calculated.

A Metallurgist has been added to the staff to make study of mill records of the test rollings in an endeavor to tie up abnormalities in chemistry or in mill practice with results of laboratory tests already made on the finished test rails.

This work will be continued and expanded during the coming year and your Committee is pleased to report substantial progress.

Appendix C

(3) RAIL FAILURE STATISTICS FOR 1932

By W. C. Barnes, Engineer of Tests, Rail Committee

The Rail Failure statistics for the year ending December 31, 1932, appearing in this report have been compiled in accordance with the standard method of basing the failure rates on mile years of service in track.

The reported tonnages and track miles of rollings for 1927 and succeeding years embodied in these statistics are as follows:

Year Rolled	*Tons*	*Track Miles*
1927	1,775,594	10,479
1928	1,682,899	9,742
1929	1,707,783	9,709
1930	1,210,343	6,852
1931	620,483	3,521
Totals	6,997,102	40,303

Table 1 shows the average failures per 100 track miles of rail in service which occurred in one to five years service of all rail reported, from all mills, together with results taken from previous reports which include both Bessemer and Open Hearth rail. The 1927 rollings, whose period of observation is now concluded, show an average of 112.4 failures per 100 track miles during the five year period, a decrease of 18.9 failures under those reported last year for the 1926 rollings but substantially the same rate as previously reported for rollings of 1922 to 1925 inclusive.

Fig. 1 shows diagrammatically the five year averages from Table 1.

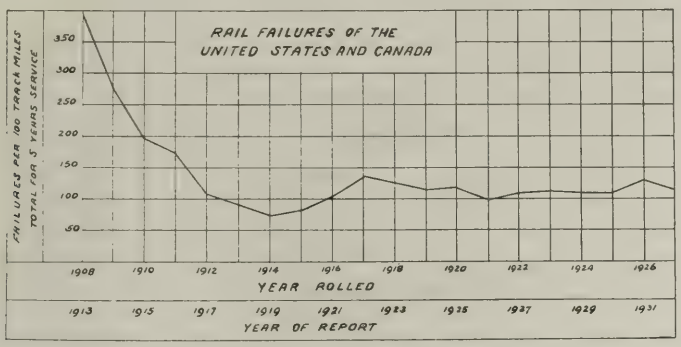


Fig. 1

Table 2 presents a summary from 20 annual reports showing track miles of rail originally laid and total failures in addition to the failures per 100 average track miles of rail in service for periods of one to five years.

Table 3 gives the failure rates of rail from each of the mills for rollings since 1908 for one to five year periods.

Fig. 2 shows diagrammatically the data from Table 3. Abnormal increases in failure rates in the 1927 as compared with the 1926 rollings, from Maryland and Algoma mills are indicated.

Table 4 presents a recapitulation of the performances during the five year period of rail rolled at each of the mills. In this table the original track miles laid from the various rollings are given as information, the failure rates being computed from the average track miles in service during the period.

Fig. 3 presents diagrammatically the average "per year" failure rates per 100 average track miles in service of the 1927 to 1931 rollings from the various mills from Table 4. These rates do not take into consideration the traffic carried. Inland shows the lowest failure rate of 4.8 followed closely by Minnequa with a rate of 7.1 and Gary with a rate of 9.2. Maryland shows the highest failure rate of 36.4 closely followed by Steelton and Ensley. The average rate for all mills is 17.4. Algoma and Dominion mills have not been included in Fig. 3 and 4 because of the comparatively small tonnages reported.

Fig. 4 rates the performances of the mills from the same data that underlie Fig. 3 except that traffic density factors have been introduced into the final computation. From the annual freight gross ton miles per mile of main track of each reporting road applied to its track mile years of rail of each of the 1927 to 1931 rollings from any given mill, the weighted average traffic over all of that mill's rail which was reported on, was determined. In like manner the weighted average traffic over all rail from each of the

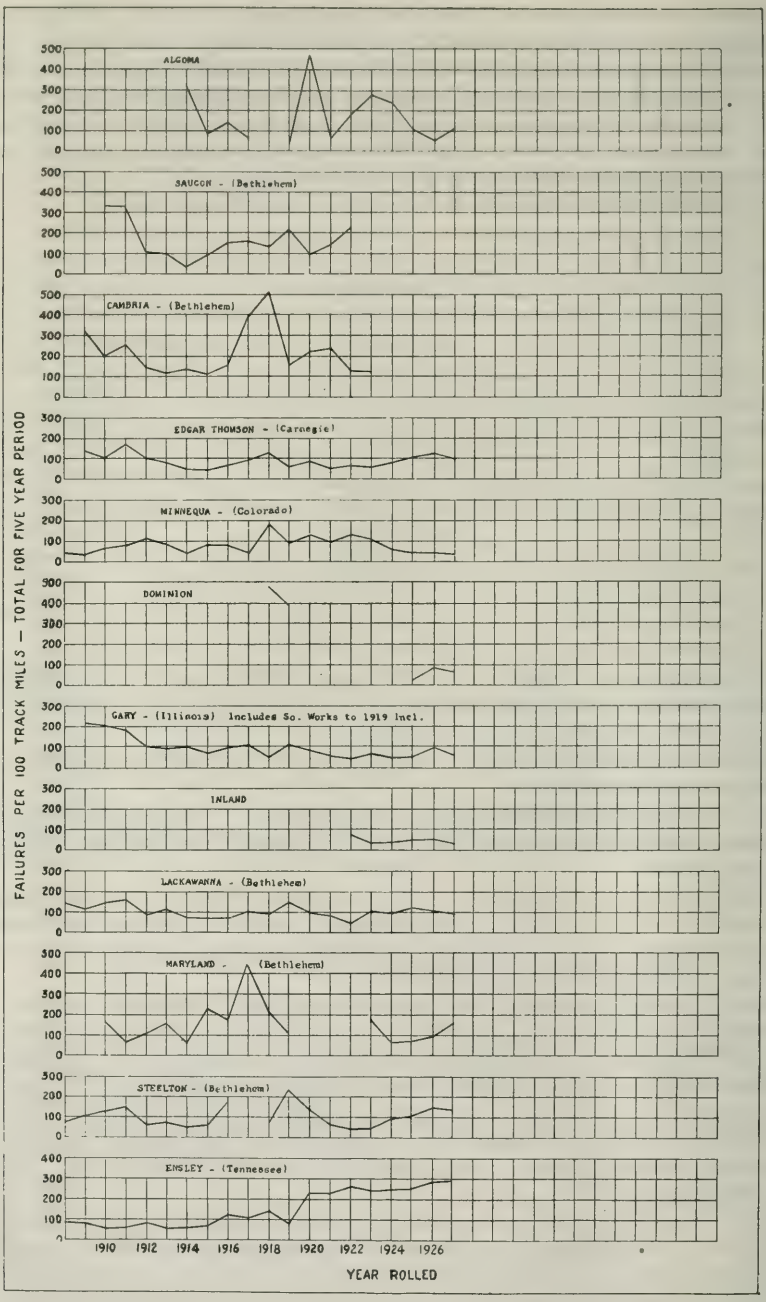


FIG. 2.—Record of Failures per 100 Track Miles for Five Years' Service for Rollings from 1908 to 1927.

other mills was separately determined. The mill whose rail was subjected to the lightest traffic was then considered to have unit traffic density and relative traffic density factors were determined for each of the other mills, which were applied to the failure rates of the respective mill outputs given in Fig. 3. No claim is made that this method of rating is entirely accurate but it does give more consideration to the work which the rails from the various mills were called upon to perform than does the method of rating underlying Fig. 3 which takes no account of traffic.

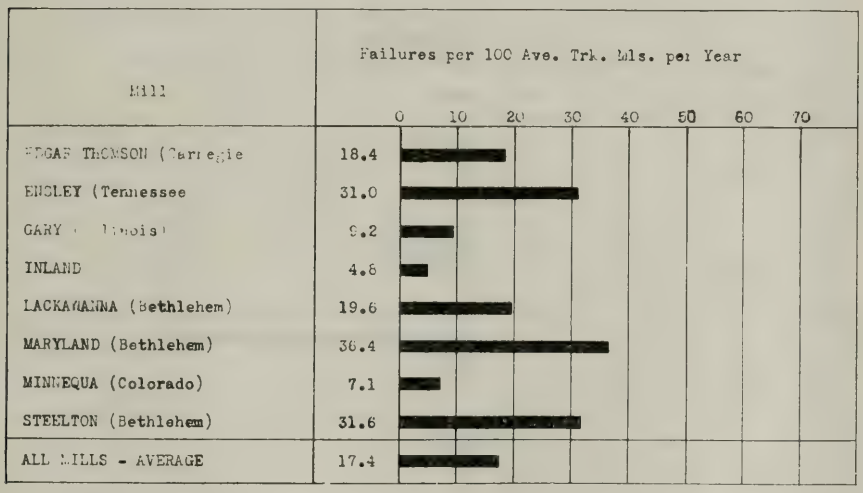


FIG. 3.—Average Failure Rates for the Rollings of 1927 to 1931 Inclusive, Classified by Mills.

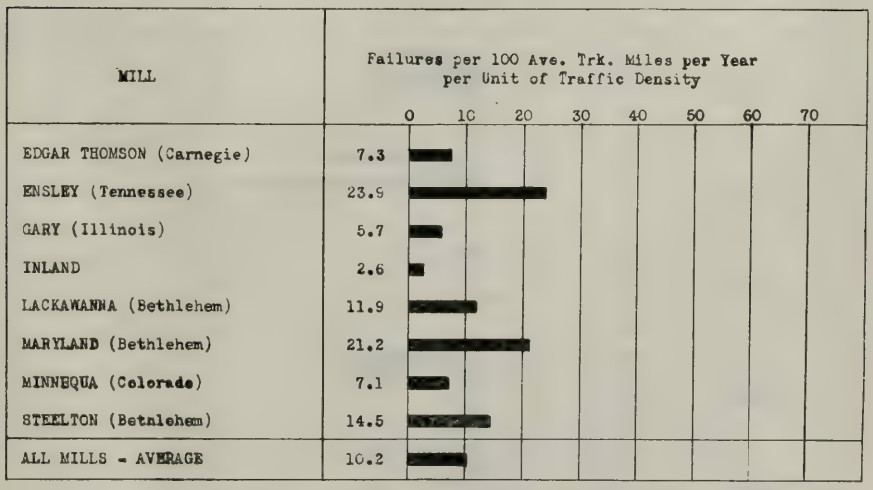


FIG. 4.—This Diagram is presented as information only. It shows Average Failure Rates for the Rollings of 1927 to 1931, inclusive, Classified by Mills, changed from those presented in Fig. 3.

The use of traffic density factors has resulted as follows: Inland remains in first place with the lowest failure rate, Gary has moved up into second place very closely followed by both Minnequa and Edgar Thomson and Ensley has moved to the lowest rank. The average traffic on Steelton and Maryland rails have improved their position in respect to Ensley.

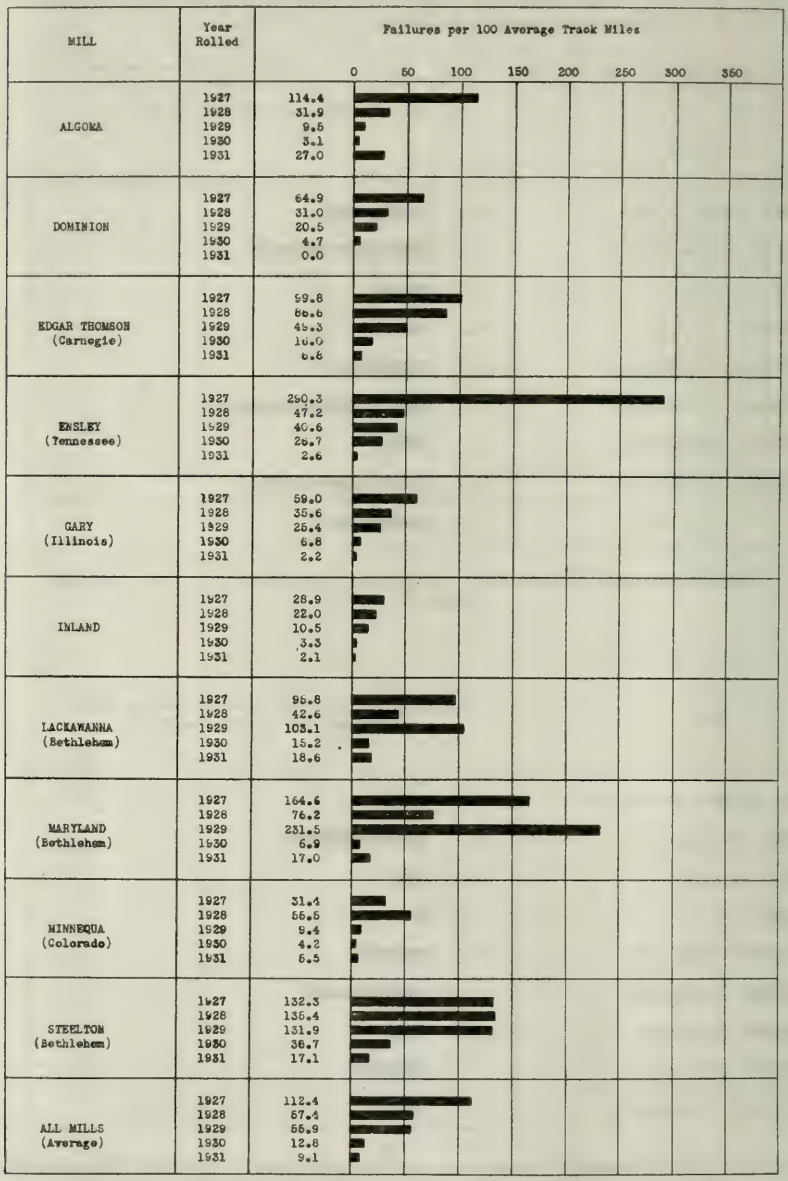


Fig. 5.—Accumulated Failures for Rollings from 1927 to 1931 Inclusive.

Fig. 5 presents diagrammatically the "total" failure rates by mills and by years rolled from Table 4. The improvement in Ensley rails of the 1928 to 1931 rollings as compared with the 1927 rolling is marked.

Table 5 shows the average weights of rail from the various mills and from all mills included in these statistics. The average weight for all mills is substantially constant for the 1929 to 1931 rollings.

TABLE 1

AVERAGE FAILURES PER 100 TRACK MILES—ALL MILLS

Year Rolled	Years Service				
	1	2	3	4	5
1908					398.1
1909				224.1	277.8
1910			124.0	152.7	198.5
1911		77.0	104.4	133.3	176.3
1912	28.9	32.1	49.3	78.9	107.1
1913	12.5	25.8	44.8	69.5	91.9
1914	8.2	19.8	32.9	50.9	74.0
1915	8.9	19.0	34.2	53.0	82.4
1916	11.8	29.2	47.7	70.6	105.4
1917	21.6	38.9	66.0	110.5	137.0
1918	8.9	27.6	54.0	92.8	125.4
1919	14.8	39.4	73.7	104.8	115.7
1920	14.2	32.4	63.1	84.5	119.6
1921	10.9	34.9	56.9	70.9	98.9
1922	15.9	34.8	55.2	80.4	110.0
1923	14.3	33.2	57.6	86.0	114.1
1924	14.0	33.4	58.3	82.0	110.7
1925	15.5	36.6	58.3	76.6	110.7
1926	17.1	41.2	64.6	102.6	131.3
1927	18.4	37.7	69.5	94.6	112.4
1928	11.0	28.0	45.8	57.4	
1929	14.1	36.8	55.9		
1930	7.8	12.8			
1931	9.1				

TABLE 2

SUMMARY FROM TWENTY ANNUAL REPORTS SHOWING TRACK MILES ORIGINALLY LAID, TOTAL FAILURES AND FAILURES PER 100 AVERAGE TRACK MILES IN SERVICE

Service	*Five Years*			*Four Years*			*Three Years*			*Two Years*			*One Year*		
	Trk Mls of Rail Laid	Failures		Trk Mls Of Rail	Failures		Trk Mls Of Rail Laid	Failures		Trk Mls Of Rail Laid	Fai.ures		Trk Mls Of Rail Laid	Failures	
		Total	Per 100 Trk Mls		Total	Per 100 Trk Mls		Total	Per 100 Trk Mls		Total	Per 100 Trk Mls		Total	Per 100 Trk Mls
FROM 1913 REPORT															
Year Rolled Totals	3201.35	1908 12746	398.1	6340.54	1909 14208	224.1	9860.18	1910 12227	124.0	6536.05	1911 5030	77.0	7105.74	1912 2050	28.9
FROM 1914 REPORT															
Year Rolled Totals	6697.39	1909 18605	277.8	10024.85	1910 15309	152.7	6096.48	1911 6354	104.4	7610.60	1912 2431	32.1	8775.44	1913 1095	12.5
FROM 1915 REPORT															
Year Rolled Totals	11587.43	1910 22981	198.5	7980.75	1911 10635	133.3	10374.18	1912 5119	49.3	10668.59	1913 2756	25.8	7061.24	1914 584	8.2
FROM 1916 REPORT															
Year Rolled Totals	7969.41	1911 14052	176.3	10260.93	1912 8100	78.9	11335.41	1913 5076	44.8	7505.24	1914 1483	19.8	7381.29	1915 656	8.9
FROM 1917 REPORT															
Year Rolled Totals	10778.68	1912 11546	107.1	12526.60	1913 8706	69.5	7819.79	1914 2576	32.9	7344.65	1915 1395	19.0	8532.53	1916 1004	11.8
FROM 1918 REPORT															
Year Rolled Totals	11883.57	1913 10924	91.9	7752.27	1914 3948	50.9	7072.23	1915 2414	34.2	8347.44	1916 2439	29.2	7384.26	1917 1596	21.6

From 1919 Report

Year Rolled Totals	7917.26	1914 5855	74.0	7280.51	1915 3862	53.0	8407.55	1916 4013	47.7	7615.46	1917 2962	38.9	6354.44	1918 568	8.9

From 1920 Report

Year Rolled Totals	7346.50	1915 6057	82.4	8062.10	1916 5691	70.6	7334.40	1917 4844	66.0	6658.80	1918 1837	27.6	6676.60	1919 986	14.8

From 1921 Report

Year Rolled Totals	7820.14	1916 8248	105.4	7025.25	1917 7765	110.5	6313.98	1918 3414	54.0	6271.82	1919 2477	39.4	7341.71	1920 1044	14.2

From 1922 Report

Year Rolled Totals	6945.43	1917 9533	137.0	6117.93	1918 5681	92.8	6402.43	1919 4719	73.7	7550.63	1920 2448	32.4	7421.29	1921 806	10.9

From 1923 Report

Year Rolled Totals	5756.11	1918 7221	125.4	6388.57	1919 6697	104.8	7200.83	1920 4545	63.1	7338.52	1921 2568	34.9	7116.16	1922 1135	15.9

From 1924 Report

Year Rolled Totals	5913.86	1919 6845	115.7	7271.00	1920 6146	84.5	6857.55	1921 3905	56.9	6974.38	1922 2429	34.8	9501.95	1923 1363	14.3

From 1925 Report

Year Rolled Totals	6576.48	1920 7759	119.6	6640.46	1921 4950	70.9	6765.99	1922 3514	55.2	8692.16	1923 2791	33.2	7804.78	1924 1098	14.0

From 1926 Report

Year Rolled Totals	7686.27	1921 7376	98.9	7116.14	1922 5594	80.4	9737.02	1923 5454	57.6	9371.49	1924 3130	33.4	10838.62	1925 1701	15.5

TABLE 2—Continued

SUMMARY FROM TWENTY ANNUAL REPORTS SHOWING TRACK MILES ORIGINALLY LAID, TOTAL FAILURES AND FAILURES PER 100 AVERAGE TRACK MILES IN SERVICE—Continued

Service	*Five Years*			*Four Years*			*Three Yeass*			*Two Years*			*One Year*		
	Trk Mls of Rail Laid	Failures		Trk Mls Of Rail	Failures		Trk Mls Of Rail Laid	Failures		Trk Mls Of Rail Laid	Fai.ures		Trk Mls Of Rail Laid	Failures	
		Total	Per 100 Trk Mls		Total	Per 100 Trk Mls		Total	Per 100 Trk Mls		Total	Per 100 Trk Mls		Total	Per 100 Trk Mls
FROM 1927 REPORT															
Year Rolled Totals	6997.42	1922 7341	110.0	9657.09	1923 7809	86.0	9036.17	1924 5014	58.3	10344.83	1925 3620	36.6	10380.45	1926 1742	17.1
FROM 1928 REPORT															
Year Rolled Totals	8106.35	1923 9253	114.1	7916.99	1924 6493	82.0	9159.06	1925 5342	58.3	9286.90	1926 3824	41.2	8527.64	1927 1567	18.4
FROM 1929 REPORT															
Year Rolled Totals	8817.34	1924 9201	110.7	10276.68	1925 7672	76.6	11164.54	1926 6945	64.6	9951.44	1927 3675	37.7	9518.72	1928 1027	11.0
FROM 1930 REPORT															
Year Rolled Totals	10161.96	1925 10697	110.7	11234.30	1926 10662	102.6	10085.95	1927 6741	69.5	9510.08	1928 2544	28.0	9229.51	1929 1253	14.1
FROM 1931 REPORT															
Year Rolled Totals	11202.92	1926 13967	131.3	10417.05	1927 9141	94.6	9686.46	1928 4246	45.8	9721.24	1929 3390	3 5.8	6029.69	1930 470	7.8
FROM 1932 REPORT															
Year Rolled Totals	10479.47	1927 11236	112.4	9742.46	1928 5382	57.4	9708.54	1929 5175	55.9	6851.68	1930 827	12.8	3520.55	1931 320	9,1

TABLE 3

FAILURES PER 100 TRACK MILES IN 1908 TO 1931 ROLLINGS IN ONE TO FIVE YEAR SERVICE PERIODS BY MILLS

Years Service	Year Rolled																							
	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931
ALGOMA																								
1					124.0		19.0	7.1	22.7	2.0		7.3	2.6	4.6	17.4	30.3	18.5	2.3	1.2	21.1	6.7	3.6	2.3	27.0
2				219.7			43.2	11.8	42.1	2.0		26.6	16.5	13.4	51.7	74.5	48.9	7.9	7.5	45.0	15.4	5.2	3.1	
3			431.0				67.1	22.9	63.4	9.1		55.8	41.0	27.0	83.0	115.8	85.7	30.3	18.8	69.9	30.7	9.5		
4		203.7					67.9	39.1	96.8	29.7		82.9	278.5	42.4	125.5	161.8	151.5	59.6	32.3	94.4	31.9			
5	482.9		13.8				321.4	84.0	139.9	62.9		36.7	472.0	65.2	184.4	276.3	236.2	113.3	52.7	114.4				
CAMBRIA—(Bethlehem)																								
1					17.1	26.7	15.8	6.3	7.3	23.9	32.9	33.3	37.6	13.8	16.1	12.6								
2				73.7	41.8	49.5	37.7	19.5	25.9	38.9	95.5	75.2	44.2	43.2	43.9	36.9								
3			98.5	126.1	74.3	78.3	61.9	34.1	33.7	112.9	248.0	82.6	96.8	101.2	62.0	63.3								
4		244.8	136.4	227.7	108.9	106.2	64.3	58.7	73.7	311.6	369.7	103.2	158.5	158.8	72.0	97.3								
5		326.6	201.0	257.2	140.9	120.1	137.7	111.5	157.6	394.2	507.4	152.7	223.1	237.4	126.0	123.5								
EDGAR THOMSON—(Carnegie)																								
1					12.3	8.9	5.5	1.8	4.9	6.1	6.2	8.5	7.0	3.3	8.4	4.1	10.6	17.1	17.2	11.2	10.3	6.2	11.6	6.8
2				71.5	30.9	19.4	11.9	8.6	13.2	19.5	41.6	35.9	15.1	8.6	20.4	13.9	33.8	41.9	30.9	23.4	31.5	31.0	16.0	
3			98.9	108.9	55.3	33.8	16.6	16.9	26.8	39.3	50.2	36.5	34.4	23.6	38.0	26.0	48.4	53.0	50.9	42.7	66.1	49.3		
4		104.1	112.9	123.1	78.4	62.9	25.4	29.2	45.6	73.3	73.7	46.5	59.4	37.5	48.7	45.9	63.0	74.8	81.5	98.5	86.6			
5		137.1	101.1	165.6	98.8	80.0	48.8	43.7	69.7	92.2	125.5	60.5	87.8	52.8	65.5	58.2	79.3	102.5	120.7	99.8				
DOMINION																								
1												5.7		60.9				2.6	1.3	6.3	5.3	6.4	0.0	0.0
2											60.0	102.3						2.6	5.8	14.2	15.9	12.6	4.7	
3											149.0	185.9						2.7	24.0	25.3	26.8	20.5		
4											420.9	298.3						7.1	49.9	41.1	31.0			
5											482.7	396.0						22.1	86.2	64.9				

TABLE 3—Continued

FAILURES PER 100 TRACK MILES IN 1908 TO 1931 ROLLINGS IN ONE TO FIVE YEAR SERVICE PERIODS BY MILLS

Years Service	Year Rolled																							
	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931
ENSLEY—(Tennessee)																								
1					7.3	5.7	7.5	6.0	15.6	17.3	16.4	14.1	39.9	37.5	42.7	42.4	32.6	35.5	34.6	48.4	12.6	17.9	18.4	2.6
2				14.9	32.9	16.5	16.6	16.0	37.1	35.7	34.6	34.2	83.1	84.9	106.7	100.4	82.4	96.1	89.9	113.6	31.9	30.5	26.7	
3			32.4	25.1	43.9	24.5	29.0	30.5	61.1	58.2	79.9	100.7	149.3	149.7	172.0	136.2	136.4	160.3	150.5	222.4	41.1	40.6		
4		11.1	47.8	40.8	64.5	41.6	44.2	48.0	82.2	102.5	143.1	132.3	189.8	184.7	204.7	194.5	181.5	168.7	241.1	258.2	47.2			
5	86.5	83.7	55.2	61.7	83.2	57.3	60.8	70.9	123.4	109.5	145.3	79.7	232.4	231.6	264.9	245.3	249.6	252.3	286.4	290.3				
GARY—(Illinois) includes So. Works to 1919 inclusive																								
1					7.4	10.0	11.6	10.7	11.1	9.1	2.5	11.5	5.4	4.2	5.0	6.6	5.4	5.6	8.2	12.8	12.0	11.3	3.6	2.2
2				67.5	23.2	21.9	30.0	21.9	26.0	19.9	10.8	26.8	13.3	16.2	11.2	17.2	10.9	10.9	22.9	20.4	24.2	20.4	6.8	
3			88.4	94.0	39.2	44.0	47.3	40.9	43.9	46.3	18.5	43.7	36.9	27.0	20.6	32.5	18.8	20.9	42.7	30.9	31.5	25.4		
4		151.9	136.8	107.7	64.6	62.1	83.6	56.1	70.7	75.5	45.4	77.1	55.6	41.7	29.4	51.1	23.2	34.5	68.4	45.7	35.6			
5		219.7	206.2	178.6	100.0	91.5	98.3	78.8	97.3	107.7	50.3	107.1	84.2	58.9	42.6	72.9	44.4	50.3	98.4	59.0				
INLAND																								
1																7.6	2.6	5.6	10.7	2.5	4.6	4.1	1.4	2.1
2															19.0	12.8	6.7	10.4	16.7	7.8	12.1	8.0	3.3	
3															35.7	20.4	16.7	21.8	30.8	13.4	17.9	10.5		
4															53.1	29.5	22.2	30.1	44.3	19.9	22.0			
5															75.7	33.4	38.2	44.2	51.2	28.9				
LACKAWANNA—(Bethlehem)																								
1					4.8	17.2	1.8	10.5	8.9	16.8	7.4	22.8	14.5	3.8	4.0	18.6	18.5	16.7	24.6	37.1	8.6	28.0	7.0	18.6
2				29.5	20.1	31.4	10.0	23.8	25.5	31.6	23.7	51.9	27.1	19.0	13.6	35.9	29.3	36.0	41.9	33.0	17.5	57.3	15.2	
3			42.7	57.1	39.6	51.9	24.5	38.1	40.1	46.6	43.8	77.4	50.6	41.3	22.6	57.6	50.8	50.9	50.3	49.3	27.4	103.1		
4		100.1	90.3	108.6	67.1	74.0	49.3	57.3	58.0	78.3	65.5	86.7	74.1	62.4	36.6	90.8	59.5	86.8	78.6	70.7	42.6			
5	143.5	117.8	148.9	162.5	88.6	115.3	78.7	73.1	76.9	104.5	93.2	153.0	99.0	83.2	49.9	108.6	97.2	122.3	105.0	95.8				

Maryland—(Bethlehem)

1					11.3	28.6	13.3	24.5	30.7	160.5	23.7	34.2	0.0	0.0				11..2	31.0	62.1	20.2	15.6	3.4	17.0
2				32.9	5.8	74.1	25.2	60.2	61.8	214.2	59.2	52.8	2.3	7.2			1.5	62..6	72.9	53.5	37.6	147.8	6.9	
3			69.6	49.5	18.1	88.4	31.4	99.6	92.6	360.5	113.6	60.8	11.9	25.3			6.0	61..9	53.2	85 5	52.9	231.5		
4			104.8	58.5	8.6	117.0	36.2	138.1	96.6	425.5	139.1	90.8	11.9				35.4	55..9	53.8	131.2	76.2			
5			163.7	67.4	110.8	159.7	62.9	231.4	180.3	445.5	210.3	106.9				180.0	65.4	77..1	97.4	164.6				

Minnequa—(Colorado)

1					18.3	3.9	3.7	4.6	5.8	5.4	6.5	5.0	9.3	9.2	12.0	7.0	4.3	3.8	2.8	2.1	3.8	2.0	2.7	5.5
2				15.8	40.9	11.0	7.6	7.7	15.7	12.5	13.1	18.5	27.6	31.7	27.1	29.3	9.6	7.2	8.9	4.6	22.7	6.0	4.2	
3			19.6	31.0	55.6	26.0	14.1	15.1	34.5	36.7	39.7	32.9	75.0	50.6	58.9	54.3	28.7	19.1	20.0	12.3	43.4	9.4		
4		22.4	23.4	52.6	91.3	46.6	27.3	34.4	53.6	51.5	109.0	65.2	96.5	72.7	111.6	91.5	39.2	32.0	30.6	19.7	55.5			
5	45.5	34.2	60.9	84.3	117.6	82.1	42.0	80.3	78.1	42.6	184.8	90.2	138.3	97.8	136.6	108.9	57.8	47.6	46.3	31.4				

Saucon—(Bethlehem)

1					11.9	13.4	3.8	17.1	17.7	39.0	19.6	31.2	10.5	12.9	55.6									
2				113.3	32.0	26.9	6.9	24.5	42.4	59.2	57.7	72.3	57.5	63.4	77.3									
3			174.0	195.3	52.1	52.6	16.0	41.0	75.2	94.8	78.4	105.0	56.5	88.4	130.6									
4		466.1	245.0	251.7	83.2	77.3	21.6	65.0	110.9	127.7	91.5	160.7	84.5	114.3	177.4									
5	503.7		330.9	329.8	106.8	99.5	33.0	92.4	152.0	157.5	133.7	213.9	95.5	143.5	223.4									

Steelton—(Bethlehem)

1					5.3	9.6	8.2	6.3	35.6		2.4	46.9	56.3	4.9	10.3	10.0	16.6	7.8	20.2	13.7	21.3	40.8	19.8	17.1
2				34.6	15.6	21.0	21.1	18.1	46.1		9.2	79.6	38.5	12.2	18.7	16.7	38.9	34.3	41.0	34.4	56.1	88.0	36.7	
3			81.4	79.6	27.5	34.7	29.4	27.9	94.2		20.7	139.8	73.2	25.9	20.1	31.2	65.3	50.6	62.3	77.2	105.1	131.9		
4		86.3	110.9	119.0	46.8	47.2	38.0	48.4	136.1		50.6	175.1	96.7	41.6	29.7	41.1	80.1	77.5	107.8	104.8	135.4			
5	72.9	101.4	123.8	145.2	60.4	71.2	49.7	59.6	171.7		76.0	233.8	139.5	66.1	43.9	49.4	95.9	113.2	144.9	132.3				

All Mills

1					26.3	11.5	8.0	8.8	11.7	21.8	8.9	14.8	14.2	10.8	15.9	14.3	14.0	15.5	17.1	18.4	11.0	14.1	7.8	9.1
2				53.0	28.9	24.8	18.9	19.0	27.9	38.9	27.6	39.4	32.4	34.9	34.8	33.2	33.4	36.6	41.2	37.7	28.0	36.8	12.8	
3			81.3	83.5	46.0	43.3	30.8	33.8	47.7	66.0	54.0	73.7	63.1	56.9	55.2	57.6	58.3	58.3	64.6	69.5	45.8	55.9		
4		163.6	107.1	111.2	74.2	68.5	47.4	53.0	70.6	110.5	92.8	104.8	84.5	70.9	80.4	86.0	82.0	76.6	102.6	94.6	57.4			
5	370.5	198.5	154.0	161.9	102.7	90.3	74.0	82.4	105.4	137.0	125.4	115.7	119.6	98.9	110.0	114.1	110.7	110.7	131.3	112.4				

TABLE 4.—RECAPITULATION—TOTALS AND AVERAGES GROUPED BY MILLS. TRACK MILES—REPRESENT QUANTITIES ORIGINALLY LAID. FAILURES TO DATE—COMPUTED BY MILE YEARS OF RAIL IN SERVICE

Year Rolled	Original Trk. Mls.	Total Failures	Failures to Date Per 100 Av. Trk. Mls		Original Trk. Mls.	Total Failures	Failures to Date Per 100 Av. Trk. Mls.	
			Total	Per Year			Total	Per Year
	Algoma				Dominion			
1927	186.70	213	114.4	22.9	63.43	41	64.9	12.9
1928	786.71	251	31.9	8.0	119.35	37	31.0	7.8
1929	778.21	74	9.5	3.2	63.49	13	20.5	6.8
1930	477.03	15	3.1	1.6	63.88	3	4.7	2.4
1931	330.43	89	27.0	27.0	46.74	0	0.0	0.0
Totals	2559.08	642	Ave.	8.3	356.89	94	Ave.	8.1
	Edgar Thomson (Carnegie)				Ensley (Tennessee)			
1927	1400.59	1338	99.8	20 0	1684.47	4586	290.3	58.1
1928	1170.40	993	86.6	21.7	1402.27	632	47.2	11.8
1929	1396.45	656	49.3	16.4	1100.22	435	40.6	13.5
1930	826.34	129	16.0	8.0	965.00	249	26.7	13.3
1931	443.78	30	6.8	6.8	740.79	19	2.6	2.6
Totals	5237.56	3196	Ave.	18.4	5892.75	5921	Ave.	31.0
	Gary (Illinois)				Inland			
1927	2357.02	1349	59.0	11.8	897.04	244	28.9	5.8
1928	2227.04	767	35.6	8.9	757.65	157	22.0	5.7
1929	1991.07	477	25.4	8.4	666.96	67	10.5	3.5
1930	1659.72	103	6.8	3.4	630.44	18	3.3	1.6
1931	688.34	15	2.2	2.2	188.95	4	2.1	2.1
Totals	8923.19	2711	Ave.	9.2	3141.04	490	Ave.	4.8
	Lackawanna (Bethlehem)				Maryland (Bethlehem)			
1927	1006.09	862	95.8	19.2	580.54	905	164.6	32.9
1928	720.63	276	42.6	10.7	441.19	325	76.2	19.1
1929	946.68	858	103.1	34.4	575.84	1258	231.5	77.2
1930	538.48	75	15.2	7.6	370.30	24	6.9	3.5
1931	312.95	58	18.6	18.6	218.64	37	17.0	17.0
Totals	3524.83	2129	Ave.	19.6	2186.51	2549	Ave.	36.4
	Minnequa (Colorado)				Steelton (Bethlehem)			
1927	1262.72	395	31.4	6.3	1040.87	1303	132.3	26.4
1928	1024.70	564	55.5	13.9	1092.52	1380	135.4	33.8
1929	1216.77	112	9.4	3.1	972.85	1225	131.9	47.3
1930	766.89	32	4.2	2.1	553.60	179	36.7	18.4
1931	220.96	12	5.5	5.5	328.97	56	17.1	17.1
Totals	4492.04	1115	Ave.	7.1	3988.81	4143	Ave.	31.6
	All Mills							
1927	10479.47	11236	112.4	22.5				
1928	9742.46	5382	57.4	14.4				
1929	9708.54	5175	55.9	18.6				
1930	6851.68	827	12.8	6.4				
1931	3520.55	320	9.1	9.1				
Totals	40302.70	22940	Ave.	17.4				

TABLE 5.—AVERAGE WEIGHTS OF RAILS COMPILED FROM TONNAGES USED IN THIS REPORT

Mill	1927	1928	1929	1930	1931
Algoma	100.2	100.7	101.1	101.2	102.0
Dominion	101.4	114.8	127.0	127.0	107.8
Edgar Thomson (Carnegie)	114.7	119.7	120.8	122.1	126.6
Ensley (Tennessee)	100.2	103.0	102.2	102.8	100.9
Gary (Illinois)	106.6	108.9	111.1	110.2	111.2
Inland	104.8	108.9	110.7	111.3	108.8
Lackawanna (Bethlehem)	107.1	109.6	114.6	117.7	119.8
Maryland (Bethlehem)	113.0	115.3	116.2	114.6	110.3
Minnequa (Colorado)	102.4	101.7	104.8	107.2	104.9
Steelton (Bethlehem)	122.2	122.5	123.7	130.0	130.6
All Mills	107.8	109.8	111.9	111.3	112.0

Appendix D

(3) TRANSVERSE FISSURE STATISTICS

By W. C. BARNES, Engineer of Tests, Rail Committee

These statistics constitute a cumulative record of 65,281 transverse fissure failures which have been reported up to and including December 31, 1932. They include all fissured rails reported whether located by actual breakage in track or detected before breakage by inspection or test.

Table 1 corresponds with Table 1 of last years report and shows the number of transverse fissure failures reported by each of 54 roads and the years in which such failures occurred. The service and detected failures which occurred each year are listed separately and the combined accumulated totals to December 31, 1932 are given. The total failures for any year on any road can be obtained by adding the service failures and the detected failures for that year.

The accumulated grand total of fissure failures, service and detected, reported to December 31, 1932 from all rollings was 65,281 or an addition during the year of 7054, which is 427 less than were reported in 1931. This decrease is accounted for by a reduction of 171 service failures and 256 detected failures. This decrease in total service and detected failures, as will be seen from Fig. 1, is the first that has occurred since the year 1924.

Fig. 1 presents graphically the total fissure failures reported each year. The dotted curve includes "detected" fissure failures while the solid curve excludes them. The broken line curve presented this year for the first time shows the detected fissure failures only. The change in slope of the curve of actual service failures co-incident with the start of Detector Car work in 1929 is noteworthy. The downward slope, during the year 1932, of the dotted curve showing all fissure failures no doubt results from the detection work carried on during that and previous years and from decreased traffic.

Table 2 corresponds with Table 2 of last years report. It shows all transverse fissure failures accumulated from year rolled to December 31, 1932, for each years rollings from each mill, unweighted by tonnage output of mills, by density of traffic or by years of service. This Table is most useful in comparing the failures in the

various years rollings from any one mill. Study of this table will disclose wide variations in the total failures in the different years rollings of several of the mills. The most recent example of this is in the 1929 rollings from Sparrows Point (Maryland), compared with its earlier and later rollings.

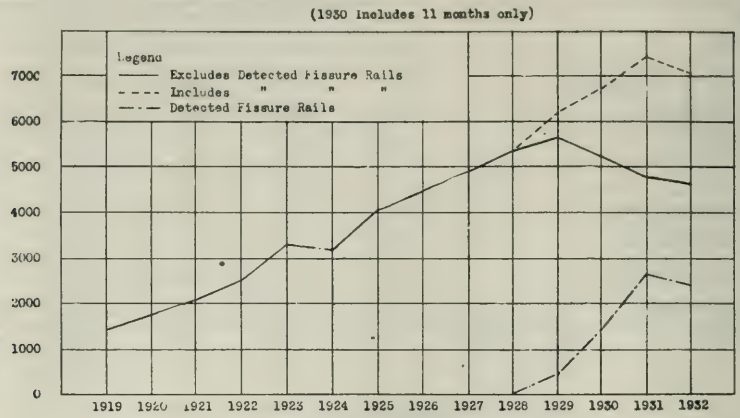


Fig. 1.—Total Fissure Failures Reported Each Year

Fissure failures reported since 1924 as occurring in the first year of service are as follows:

29	Failures	in	1925	from	1925	Rollings,	All	Mills
50	"	"	1926	"	1926	"	"	"
114	"	"	1927	"	1927	"	"	"
58	"	"	1928	"	1928	"	"	"
106	"	"	1929	"	1929	"	"	"
33	"	"	1930	"	1930	"	"	"
32	"	"	1931	"	1931	"	"	"
3	"	"	1932	"	1932	"	"	"

The small number of first year failures in the 1932 rail is no doubt influenced by light traffic as well as by the small tonnage of 1932 rail purchased.

Table 3 corresponds with Table 3 of last years report and shows the rate of accumulated failures on selected roads per 100 original track miles per year from year rolled to December 31, 1932. The data included are for the rollings of 1925 to 1929 inclusive and are segregated by mill and by year rolled. No account is taken in this table of differences in density of traffic over the rails from the various mills.

Table 3 includes a total of 11,431 fissure failures which occurred in 37,239 miles of track. Colorado, Inland, Gary and Carnegie mills show the lowest average accumulated failure rate per 100 track miles per year from date rolled to December 31, 1932, the respective rates being 0.41, 2.48, 2.48 and 3.62. Steelton, Lackawanna, Tennessee and Maryland produced the higher rates of 7.96, 8.16, 11.02 and 39.93 respectively, the high rate of Maryland being due to the excessive rate of 105.53 produced by its 1929 rollings.

Fig. 2 shows graphically the average rates of failure by mills from Table 3.

Fig. 3 shows graphically the average rates of failure by mills from Table 3 modified by the application of average traffic density factors. The method of obtaining these factors has been explained in detail in preceding reports.

The weighting for relative traffic density has improved the rates of those mills whose rails carried the heavier traffic and has resulted in putting Carnegie in third rank instead of Gary.

TABLE 1

TRANSVERSE FISSURE FAILURES BY RAILROADS AND YEAR FAILED

Railroad	Service Failures																Detected Failures**					Grand Total
	Prior	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930*	1931	1932	Total	1929	1930*	1931	1932	Total	
A. T. & S. F.	40	25	177	220	134	126	81	79	71	98	126	91	142	114	84	1608	--	--	--	--	--	1608
A. C. L.	--	--	--	--	--	--	--	--	11	9	27	25	21	29	37	159	--	66	--	--	66	225
Ban. & Aroos.	--	--	--	--	--	--	--	--	11	2	0	4	7	2	1	27	--	--	--	--	--	27
B. & Eastern	--	--	--	--	--	--	0	0	0	0	0	0	0	0	P.R.R.	0	--	--	--	(See P.	R. R.)	0
Boston & Albany	4	17	23	30	25	15	10	9	3	12	8	31	31	26	42	286	--	23	29	40	92	378
Boston & Maine	--	--	--	--	--	35	69	72	78	70	44	34	35	22	33	492	--	17	--	19	36	528
B. & O.	--	--	--	--	--	212	297	369	253	458	405	428	345	472	383	3622	53	--	--	182	235	3857
B. R. & P.	--	--	--	--	9	11	9	16	15	17	26	41	27	34	B.&O.	205	--	--	--	(SeeB.	& O.)	205
Can. Nat.	--	--	--	--	--	--	--	--	13	--	--	--	--	--	--	13	--	--	--	--	--	13
Can. Pacific	--	4	--	8	16	59	86	158	277	174	160	108	138	106	89	1383	--	--	351	214	565	1948
Cent. of Ga.	106	52	23	41	31	29	24	40	20	20	42	92	80	42	74	716	--	80	--	107	187	903
C. R. R. of N. J.	--	--	--	--	--	--	--	--	--	34	58	95	73	59	40	359	--	35	111	--	146	505
C. & E. I.	--	--	--	--	--	--	--	--	4	--	22	41	18	18	28	131	28	--	59	--	87	218
C. & O.	--	--	--	6	26	46	49	81	208	104	165	167	181	239	330	1575	19	376	667	323	1385	2960
C. & N. W.	--	--	--	--	--	--	--	--	85	63	47	62	101	86	110	554	16	31	110	218	375	929
C. B. & Q.	--	1	7	34	101	87	--	--	--	--	--	--	--	--	--	230	--	--	--	--	--	230
C. M. St. P. & P.	2	--	6	5	14	11	11	13	5	9	26	11	26	45	105	289	43	--	49	--	92	381
C. R. I. & P.	10	2	11	25	37	75	73	114	98	97	90	123	111	116	131	1113	20	--	18	93	131	1244
C. C. C. & St. L.	--	--	--	--	2	1	1	47	21	11	36	44	44	27	26	260	--	--	--	76	76	336
D. L. W.	474	193	240	169	91	80	73	113	128	86	92	139	98	64	102	2142	--	--	--	--	--	2142
El Paso & S. W.	--	--	--	--	8	6	(See	Sou. P	ac.)	--	--	--	--	--	--	14	--	--	--	--	--	14
Erie	--	--	--	--	15	43	89	100	118	148	128	235	156	175	181	1388	27	2	1	--	30	1418
Great Northern	--	--	--	--	--	--	--	--	--	58	221	175	189	141	126	910	--	25	--	--	25	935
Hocking Valley	--	--	--	--	13	53	82	38	2	4	30	91	(SeeC.	& O.)	--	313	3	(See	C. &	O.)	3	316
Illinois Central	11	35	121	190	372	556	419	501	614	658	615	597	439	310	281	5719	25	126	204	217	572	6291
Ind. Harbor Belt	--	--	--	--	--	1	3	3	0	0	0	0	0	0	0	7	--	--	--	--	--	7
L. & H. R.	--	--	--	1	--	4	4	16	33	10	7	8	3	11	3	100	--	--	--	--	--	100
L. & N. E.	--	--	--	--	--	32	0	0	0	0	1	0	0	6	3	42	--	--	--	--	--	42
Lehigh Valley	--	--	--	--	57	89	113	92	75	75	55	60	39	22	17	694	--	--	78	--	78	772
Long Island	--	--	--	2	8	7	11	2	3	6	(See	P.R.	R.)	--	--	39	(See	P. R.	R.)	--	--	39

TABLE 1—Continued

TRANSVERSE FISSURE FAILURES BY RAILROADS AND YEAR FAILED

Railroad	Service Failures																Detected Failures**					Grand Total
	Prior	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930*	1931	1932	Total	1929	1930*	1931	1932	Total	
L. A. & S. L.	--	--	--	--	--	--	1	7	12	36	39	32	40	49	52	268	2	--	--	--	2	270
L. & N.	474	9	17	33	43	77	90	75	141	295	374	456	285	268	220	2857	101	165	--	--	266	3123
Mich. Cent.	--	--	--	--	--	2	5	11	13	10	8	15	18	20	44	146	--	--	--	--	--	146
M. K. T.	--	--	--	2	11	13	17	29	26	33	33	30	31	32	30	287	10	12	29	76	127	414
Mo. Pac.	--	--	--	--	2	8	--	--	--	--	--	--	--	--	--	10	--	--	--	--	--	10
M. & O.	--	--	--	--	--	--	--	--	18	30	59	18	26	32	42	225	4	--	--	--	4	229
N. C. & St. L.	10	--	1	2	2	8	5	7	3	15	15	34	22	50	42	216	--	2	--	--	2	218
N. Y. C. (East)	415	84	88	93	136	107	126	165	233	257	295	300	209	183	152	2833	27	63	44	57	191	3024
N. Y. C. (West)	--	--	1	18	37	16	31	62	49	44	34	54	38	50	35	469	--	21	10	9	40	509
N. Y. C. & St. L.	--	--	--	--	--	2	--	--	--	--	--	--	--	--	--	2	--	--	--	--	--	2
N. Y., N. H. & H	--	--	--	--	12	28	26	57	63	34	27	51	40	25	24	387	17	67	159	106	349	736
N. Y. O. & W.	--	--	--	--	--	--	--	--	--	59	62	63	60	48	54	346	--	--	1	4	5	351
N. & W.	--	--	--	--	3	17	45	29	18	16	18	25	43	41	29	284	--	20	--	5	25	309
N. P.	--	--	--	--	42	39	120	161	152	184	166	160	131	171	160	1486	48	--	--	--	48	1534
Pennsylvania	2244	1114	1129	1104	904	649	501	785	868	741	574	584	572	426	317	12512	--	192	378	378	948	13460
Reading	--	--	--	--	52	112	107	91	36	42	39	53	57	100	111	800	--	--	--	--	--	800
R. F. & P.	--	--	--	--	--	--	--	--	0	0	0	1	0	1	3	5	3	--	--	--	3	8
Rutland	--	--	--	--	--	--	--	3	2	1	0	2	3	1	0	12	--	--	--	7	7	19
Sou. Pac.	57	9	6	130	118	143	175	243	335	397	530	500	458	331	322	3754	--	131	251	142	524	4278
Southern Ry.	--	--	--	--	--	24	6	13	51	123	191	205	201	183	160	1157	--	--	--	--	--	1157
Tem. & No. Ont.	--	--	--	--	--	--	--	--	--	0	0	0	0	0	0	0	--	--	--	--	--	0
Union Pacific	--	--	--	36	262	557	498	473	356	289	341	406	457	446	483	4604	32	--	137	157	326	4930
Virginian	--	--	--	--	--	--	--	--	--	--	10	12	7	24	24	77	--	--	--	--	--	77
West. Maryland	--	--	--	--	--	--	--	65	111	164	212	57	255	148	94	1106	--	--	--	--	--	1106
All Roads	3847	1545	1850	2149	2584	3382	3257	4136	4596	4993	5458	5760	5257	4795	4624	58233	478	1454	2686	2430	7048	65281

* Data given for 1930 covers 11 months from February 1st to December 31st. Prior to 1930 each year's data covers 12 months from February 1st. Subsequent to 1930 each year's data covers 12 months from January 1st.

** Detection methods first used to any extent in 1929.

TABLE 2

ACCUMULATED TRANSVERSE FISSURE FAILURES REPORTED TO DEC. 31, 1932 BY YEAR ROLLED AND BY MILL

(Includes fissured rails detected before actual failure in track)

Years Rolled	*Unknown*			*Algoma*			*Saucon (Bethlehem)*			*Cambria (Bethlehem)*			*Edgar Thomson (Carnegie)*			*Minnequa (Colorado)*			*Dominion*			*Krupp (German)*		
	Prior	1932	Total	Prior	1932	Total	Prior	1932	Total	Prior	1932	Total	Prior	1932	Total	Prior	1932	Total	Prior	1932	Total	Prior	1932	Total
Unk.	62	10	72	10	0	10	41	8	49	41	1	42	40	5	45	35	1	36	2	0	2	--	--	--
1889	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1890	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1891	--	--	--	--	--	--	--	--	--	--	--	--	1	0	1	--	--	--	--	--	--	--	--	--
1892	--	--	--	--	--	--	--	--	--	2	0	2	--	--	--	--	--	--	--	--	--	--	--	--
1893	--	--	--	--	--	--	1	0	1	1	0	1	--	--	--	--	--	--	--	--	--	--	--	--
1894	--	--	--	--	--	--	--	--	--	6	0	6	--	--	--	--	--	--	--	--	--	--	--	--
1895	--	--	--	--	--	--	--	--	--	5	0	5	1	0	1	--	--	--	--	--	--	--	--	--
1896	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1897	--	--	--	--	--	--	--	--	--	10	0	10	5	0	5	--	--	--	--	--	--	--	--	--
1898	--	--	--	--	--	--	2	0	2	17	1	18	4	0	4	--	--	--	--	--	--	--	--	--
1899	--	--	--	--	--	--	--	--	--	14	0	14	7	0	7	--	--	--	--	--	--	--	--	--
1900	--	--	--	--	--	--	--	--	--	15	0	15	8	0	8	--	--	--	--	--	--	--	--	--
1901	--	--	--	--	--	--	--	--	--	26	1	27	17	0	17	--	--	--	--	--	--	--	--	--
1902	2	0	2	--	--	--	2	0	2	62	0	62	37	2	39	1	0	1	--	--	--	--	--	--
1903	1	0	1	--	--	--	--	--	--	58	0	58	67	0	67	--	--	--	--	--	--	--	--	--
1904	6	0	6	--	--	--	--	--	--	27	0	27	40	0	40	1	0	1	--	--	--	--	--	--
1905	3	0	3	8	2	10	--	--	--	30	0	30	38	1	39	--	--	--	--	--	--	--	--	--
1906	2	0	2	--	--	--	3	0	3	67	0	67	44	1	45	1	0	1	9	1	10	--	--	--
1907	--	--	--	2	0	2	10	1	11	70	0	70	30	3	33	2	0	2	--	--	--	--	--	--
1908	--	--	--	5	0	5	231	8	239	14	1	15	--	--	--	1	0	1	87	7	94	--	--	--
1909	--	--	--	6	1	7	1467	44	1511	75	0	75	37	0	37	3	0	3	12	0	12	--	--	--
1910	14	0	14	11	0	11	730	39	769	119	1	120	22	6	28	395	17	412	--	--	--	--	--	--
1911	2	0	2	13	0	13	973	16	989	353	3	356	57	0	57	382	47	429	--	--	--	--	--	--
1912	14	0	14	7	0	7	152	4	156	651	23	674	64	6	70	77	5	82	57	2	59	--	--	--
1913	23	0	23	7	0	7	326	6	332	568	12	580	77	5	82	41	4	45	4	0	4	--	--	--
1914	2	0	2	31	4	35	146	2	148	343	4	347	38	2	40	87	8	95	9	0	9	--	--	--

TABLE 2—Continued

ACCUMULATED TRANSVERSE FISSURE FAILURES REPORTED TO DEC. 31, 1932 BY YEAR ROLLED AND BY MILL

(Includes fissured rails detected before actual failure in track)

Years Rolled	*Unknown*			*Algoma*			*Saucon (Bethlehem)*			*Cambria (Bethlehem)*			*Edgar Thomson (Carnegie)*			*Minnequa (Colorado)*			*Dominion*			*Krupp (German)*		
	Prior	1932	Total	Prior	1932	Total	Prior	1932	Total	Prior	1932	Total	Prior	1932	Total	Prior	1932	Total	Prior	1932	Total	Prior	1932	Total
1915	2	0	2	478	23	501	316	22	338	129	3	132	48	5	53	192	7	199	-	--	--	--	--	--
1916	1	0	1	109	4	113	377	7	384	93	6	99	85	7	92	439	34	473	--	--	--	--	--	--
1917	4	0	4	6	0	6	264	0	264	153	4	157	68	7	75	498	55	553	--	--	--	--	--	--
1918	2	0	2	404	9	413	91	0	91	87	5	92	73	5	78	84	13	97	83	1	84	--	--	--
1919	1	0	1	392	16	408	260	6	266	11	8	19	24	0	24	45	16	61	54	4	58	--	--	--
1920	--	--	--	86	4	90	73	0	73	64	2	66	89	5	94	344	73	417	--	--	--	--	--	--
1921	1	0	1	49	22	71	187	4	191	167	2	169	121	7	128	139	25	164	2	0	2	--	--	--
1922	--	--	--	163	67	230	122	4	126	78	2	80	185	7	192	39	10	49	--	--	--	--	--	--
1923	96	0	96	150	64	214	--	--	--	50	3	53	144	21	165	50	7	57	--	--	--	--	--	--
1924	66	0	66	153	78	231	--	--	--	--	--	--	139	17	156	40	12	52	--	--	--	--	--	--
1925	55	1	56	7	5	12	--	--	--	--	--	--	192	21	213	39	12	51	5	0	5	--	--	--
1926	22	0	22	3	0	3	--	--	--	--	--	--	339	64	403	19	9	28	6	16	22	4	2	6
1927	27	1	28	17	0	17	--	--	--	--	--	--	246	55	301	9	6	15	--	--	--	--	--	--
1928	1	0	1	28	6	34	--	--	--	--	--	--	89	71	160	6	6	12	--	--	--	--	--	--
1929	--	--	--	--	--	--	--	--	--	--	--	--	30	37	67	--	--	--	1	0	1	--	--	--
1930	--	--	--	--	--	--	--	--	--	--	--	--	5	5	10	--	1	1	--	--	--	--	--	--
1931	--	--	--	--	1	1	--	--	--	--	--	--	--	3	3	--	--	--	--	--	--	--	--	--
1932	--	--	--	--	1	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Totals	409	12	421	2145	307	2452	5774	171	5945	3406	82	3488	2511	368	2879	2969	368	3337	331	31	362	4	2	6

TABLE 2—Continued

ACCUMULATED TRANSVERSE FISSURE FAILURES REPORTED TO DEC. 31, 1932 BY YEAR ROLLED AND BY MILL

(Includes fissured rails detected before actual failure in track)

Year Rolled	*Gary* (Illinois)*			*Inland (Inland)*			*Lackawanna** (Bethlehem)*			*Lorain*			*Maryland (Bethlehem)*			*Steelton (Bethlehem)*			*Ensley (Tennessee)*			*All Mills*		
	Prior	1932	Total	Prior	1932	Total	Prior	1932	Total	Prior	1932	Total	Prior	1932	Total	Prior	1932	Total	Prior	1932	Total	Prior	1932	Total
Unk.	156	8	164	3	1	4	27	2	29	--	--	--	13	2	15	11	3	14	143	26	169	584	67	651
1889	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	0	2	--	--	--	2	0	2
1890	--	--	--	--	--	--	2	0	2	--	--	--	1	0	1	5	0	5	--	--	--	8	0	8
1891	--	--	--	--	--	--	4	0	4	--	--	--	--	--	--	3	0	3	--	--	--	8	0	8
1892	--	--	--	--	--	--	--	--	--	--	--	--	1	0	1	2	0	2	--	--	--	5	0	5
1893	--	--	--	--	--	--	--	--	--	--	--	--	4	0	4	--	--	--	--	--	--	6	0	6
1894	--	--	--	--	--	--	--	--	--	--	--	--	1	0	1	4	0	4	--	--	--	11	0	11
1895	--	--	--	--	--	--	1	0	1	--	--	--	--	--	--	2	0	2	--	--	--	9	0	9
1896	2	0	2	--	--	--	6	0	6	--	--	--	1	0	1	4	0	4	1	0	1	14	0	14
1897	--	--	--	--	--	--	9	0	9	--	--	--	1	0	1	7	1	8	--	--	--	32	1	33
1898	--	--	--	--	--	--	36	2	38	--	--	--	2	1	3	8	0	8	--	--	--	69	4	73
1899	--	--	--	--	--	--	13	0	13	--	--	--	3	0	3	18	0	18	--	--	--	55	0	55
1900	2	0	2	--	--	--	--	--	--	--	--	--	6	0	6	11	0	11	--	--	--	42	0	42
1901	2	0	2	--	--	--	23	1	24	--	--	--	14	0	14	--	--	--	--	--	--	82	2	84
1902	1	0	1	--	--	--	4	0	4	3	0	3	33	0	33	--	--	--	--	--	--	145	2	147
1903	2	0	2	--	--	--	3	0	3	--	--	--	63	0	63	--	--	--	27	0	27	221	0	221
1904	4	0	4	--	--	--	92	1	93	--	--	--	27	0	27	--	--	--	199	0	199	396	1	397
1905	6	0	6	--	--	--	16	0	16	3	0	3	32	2	34	5	0	5	325	1	326	466	6	472
1906	4	0	4	--	--	--	6	1	7	5	0	5	54	0	54	2	0	2	52	0	52	249	3	252
1907	23	1	24	--	--	--	26	0	26	--	--	--	77	0	77	--	--	--	62	0	62	302	5	307
1908	9	0	9	--	--	--	8	2	10	1	0	1	3	0	3	3	0	3	32	1	33	394	19	413
1909	886	24	910	--	--	--	79	3	82	--	--	--	71	0	71	111	1	112	6	2	8	2753	75	2828
1910	2355	98	2453	--	--	--	239	17	256	--	--	--	118	3	121	124	6	130	155	2	157	4282	189	4471
1911	270	6	276	--	--	--	354	10	364	--	--	--	232	5	237	126	4	130	170	9	179	2932	100	3032
1912	1495	80	1575	--	--	--	869	34	903	--	--	--	196	3	199	103	13	116	121	9	130	3806	179	3985
1913	1514	118	1632	--	--	--	936	35	971	1	0	1	482	16	498	123	19	142	131	11	142	4233	226	4459
1914	410	39	449	--	--	--	750	21	771	--	--	--	145	8	153	113	5	118	220	10	230	2294	103	2397

Table 2—Continued

ACCUMULATED TRANSVERSE FISSURE FAILURES REPORTED TO DEC. 31, 1932 BY YEAR ROLLED AND BY MILL

(Includes fissured rails detected before actual failure in track)

Year Rolled	*Gary* (Illinois)*			*Inland (Inland)*			*Lackawanna** (Bethlehem)*			*Lorain*			*Maryland (Bethlehem)*			*Steelton (Bethlehem)*			*Ensley (Tennessee)*			*All Mills*		
	Prior	1932	Total	Prior	1932	Total	Prior	1932	Total	Prior	1932	Total	Prior	1932	Total	Prior	1932	Total	Prior	1932	Total	Prior	1932	Total
1915	613	27	640	--	--	--	407	40	447	--	--	--	556	27	583	154	1	155	86	6	92	2981	161	3142
1916	875	97	972	--	--	--	129	4	133	--	--	--	519	41	560	33	0	33	255	10	265	2915	210	3125
1917	2317	341	2658	--	--	--	148	5	153	--	--	--	799	43	842	7	3	10	232	22	254	4496	480	4976
1918	628	118	746	--	--	--	131	5	136	--	--	--	104	11	115	15	0	15	384	51	435	2086	218	2304
1919	1294	211	1505	--	--	--	104	14	118	--	--	--	68	2	70	114	11	125	544	84	628	2911	372	3283
1920	694	105	799	--	--	--	193	15	208	--	--	--	1	1	2	171	4	175	207	20	227	1922	229	2151
1921	580	105	685	--	--	--	159	14	173	--	--	--	3	1	4	276	26	302	218	35	253	1902	241	2143
1922	240	54	294	208	18	226	176	19	195	--	--	--	6	1	7	85	5	90	414	88	502	1716	275	1991
1923	646	153	799	106	18	124	508	54	562	--	--	--	7	1	8	134	20	154	396	56	452	2287	397	2684
1924	385	90	475	116	35	151	178	32	210	--	--	--	10	2	12	261	47	308	653	141	794	2001	454	2455
1925	304	93	397	101	28	129	333	44	377	--	--	--	175	37	212	257	35	292	896	211	1107	2364	487	2851
1926	358	183	541	173	52	225	355	126	481	--	--	--	186	31	217	268	74	342	995	170	1165	2728	727	3455
1927	212	106	318	22	25	47	327	113	440	--	--	--	386	111	497	259	91	350	660	81	741	2165	589	2754
1928	29	26	55	11	10	21	114	60	174	--	--	--	213	81	294	259	91	350	94	16	110	844	367	1211
1929	15	8	23	11	4	15	78	79	157	--	--	--	849	380	1229	173	79	252	116	44	160	1273	631	1904
1930	16	50	66	1	0	1	--	3	3	--	--	--	20	29	49	157	71	228	5	5	10	204	164	368
1931	1	6	7	--	--	--	--	1	1	--	--	--	12	10	22	19	44	63	--	2	2	32	67	99
1932	--	1	1	--	--	--	--	--	--	--	--	--	--	1	1	--	--	--	--	--	--	--	3	3
Totals	16348	2148	18496	752	191	943	6843	757	7600	13	0	13	5494	850	6344	3429	654	4083	7799	1113	8912	58227	7054	65281

* Includes South Works prior to 1920.
** Prior to 1903 was Scranton Mill of Lackawanna Iron & Steel Co.

TABLE 3

AVERAGE TRANSVERSE FISSURE FAILURE RATES ON SELECTED ROADS PER 100 ORIGINAL TRACK MILES PER YEAR FROM YEAR ROLLED TO 12/31/32, BY MILL AND YEAR ROLLED

(Includes fissured rails detected before actual failure in track)

Year Rolled	E. Thom (Carn.)	Ensley Tenn.)	Gary (Ill.)	Inl. (Inl.)	Lack. (Beth.)	Mary. (Beth.)	Minn. (Colo.)	Stltn. (Beth.)	All Mills
1925	2.46	11.69	2.71	2.44	6.51	6.41	0.57	3.92	4.84
1926	5.33	12.75	3.90	4.29	7.72	36.76	0.55	8.13	6.70
1927	3.94	13.94	2.91	2.29	11.74	32.15	0.33	10.50	6.84
1928	3.80	3.04	0.58	0.89	9.99	27.63	0.38	12.78	4.45
1929	1.60	7.27	0.46	0.84	5.61	105.53	0.00	9.56	8.58
Ave.	3.62	11.02	2.48	2.48	8.16	39.93	0.41	7.96	6.14

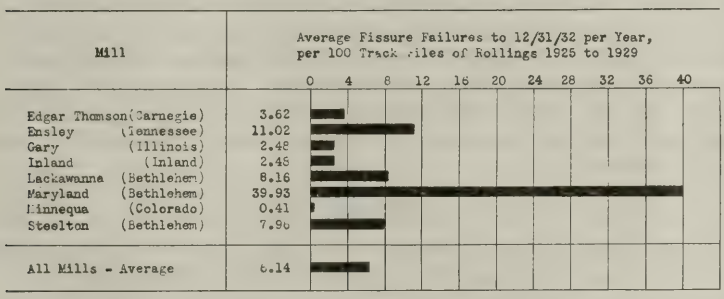


FIG. 2.—Average Failure Rates Classified by Mills
(Includes fissured rails detected before actual failure in track)

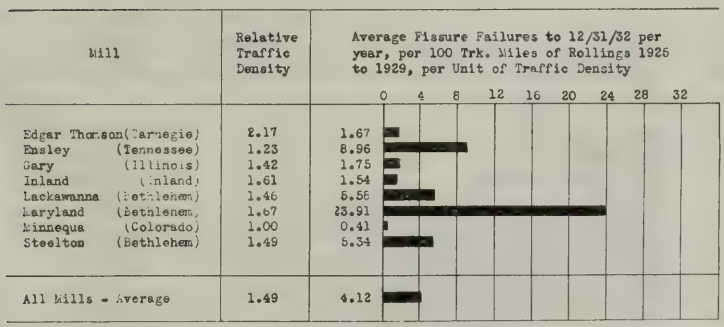


FIG. 3.—Average Failure Rates by Mills Altered by Traffic Density Factors
(Includes fissured rails detected before actual failure in track)

Appendix E

OPERATING RESULTS OF THE A.R.A. RAIL FISSURE DETECTOR CAR

By W. C. Barnes, Engineer of Tests, Rail Committee

On November 14, 1933 the A.R.A. Detector Car completed its fifth year of operation under the direction of the Rail Committee, having travelled on its own wheels a total of 50,000 miles and tested 23,181 track miles of rail in all sections of the country. Approximately 6,600 track miles were tested during the last year.

With no change in the per diem rental charge for the car ($85.00 per day independent of mileage tested) our total amount billed against lessee roads per track mile tested has been constantly reduced due to improvement in testing methods. Within the last two years this reduction has amounted to practically 28 per cent, resulting in a remarkably low cost to the railroads per mile tested.

The average track miles tested per testing day for the last 3,500 miles tested was close to 27. It is now safe to say that the average track miles that can now be tested per day varies between 20 and 27 miles, depending on the density of traffic and condition of the rail tested, with an efficiency of testing superior to any heretofore obtained.

The American Railway Association has recently approved the purchase of a more substantial car to house the detecting equipment and it is expected that this will still further decrease the cost of testing through increase in permissible speed when running light between test locations, clearing for traffic, etc.

The demand for A.R.A. testing service has been little affected by general business conditions and we are again able to say that the car has not yet been idle a single day for lack of business.

Appendix F

(4) CAUSE AND PREVENTION OF RAIL BATTERING, COLLABORATING WITH COMMITTEE V—TRACK

(9) HEAT TREATING OF RAIL ENDS TO REDUCE WEAR

F. M. Graham, Chairman, Sub-Committee; W. J. Backes, W. C. Barnes, W. A. Duff, B. Herman, E. E. Oviatt, W. H. Penfield, R. T. Scholes, J. R. Watt, C. E. Weaver, J. E. Willoughby.

The study of Subject 4—"Cause and Prevention of Rail Battering", has progressed to the point where it may be stated that the cause of rail battering is due to the very high unit static pressure between the wheel and the rail combined with impact blows of wheel on the rail. Causes which accelerate battering are:

1. Heavy wheel loads.
2. Small wheels.
3. Large joint openings.
4. Soft rail.
5. Difference in height of rails in joint.
6. Spring condition of equipment.
7. Increase of weight on low rail of curves.
8. Small radius across top of rail.
9. Poor maintenance of joint parts.

Causes Nos. 3, 4, 5, 6, 8 and 9, can be corrected or modified.

It is now believed that the most effective way to reduce rail battering consists in making the rail ends more resistent to deformation by a suitable heat treatment.

Various methods of heat treating rail ends are now being tried as follows:

1. Quenching by air blast in rail mill to desired hardness.
2. Heating rail ends in track with (free held) acetylene torch, quenching with water to 200 degrees Fahr. and drawing to desired hardness by torch heating.
3. Heating rail ends in track with acetylene torch held in carriage with controlled time of heating and limited quenching, leaving residue of heat to draw to desired hardness.
4. Preheating with gasoline stove followed by heating with electric arc moving over surface to be heated by cam movements. Heating automatically stopped when a given number of watts have been used. Quenching with circulating oil and surface then protected by insulating pad for a few minutes.

Method No. 1 has been used experimentally in a very limited way and little field testing has been done.

Method No. 2 has been very extensively used for a number of years on the C.M.St.P. & P.R.R., with very good results. Other roads are now using this method quite extensively.

Method No. 3 has been used only in a very limited test on the Pennsylvania R.R.

Method No. 4 has been used quite extensively during the past year. This method is patented and work is done under contract.

All methods aim at bringing the top of the ends of the rails to a Brinell hardness of about 350 to 400 and to a depth of something over ¼ in.

All methods quench from a temperature of about 1500 deg. Fahr.

Methods No. 1 quenches with an air blast and produces a variable degree of hardness over a considerable length and depth from the rail end.

Methods Nos. 2, 3 and 4, confine the hardening to 2 to 3 in. from the rail end.

The heat treatment of steel to obtain desired results involves much care and accuracy in the method. Attention must be given to the chemistry of the steel, the size and shape of the piece, the time of heating and temperature at the quench, the quenching medium and time of its application, the temperature at which it is drawn, also time of drawing.

In the case of rail end heat treating, the above difficulties are increased by the absorption of heat by the metal outside of the heat treated zone.

If the steel is heated for the quench too rapidly, the surface reaches the quenching temperature without sufficient penetration, and if heated too slowly, the heat treating effect is carried too deep.

If rail ends are not drawn before traffic passes over them, the resultant extreme hardness may cause the top corner at the end of the rail to shatter.

All of the above discussion applies to new rail or cropped rail; and this practice is now being used on the C.M.St.P.&P.R.R., C.&O.Ry. and the Erie Railroad with good results.

Heat treating is now being applied to welded rail ends.

Two graph sheets are attached showing the comparative results of heat treated and untreated rail ends.

Plate "A" shows results where the third method was used.

It will be noted that the ends were treated 5½ months after the rail was laid, or after 23,000,000 tons had passed over it.

These measurements show that farther batter was practically stopped by the heat treatment.

Plate "B" shows results where the second method was used. This rail was heat treated as it was laid. On account of rust and mill scale interfering with measurements,

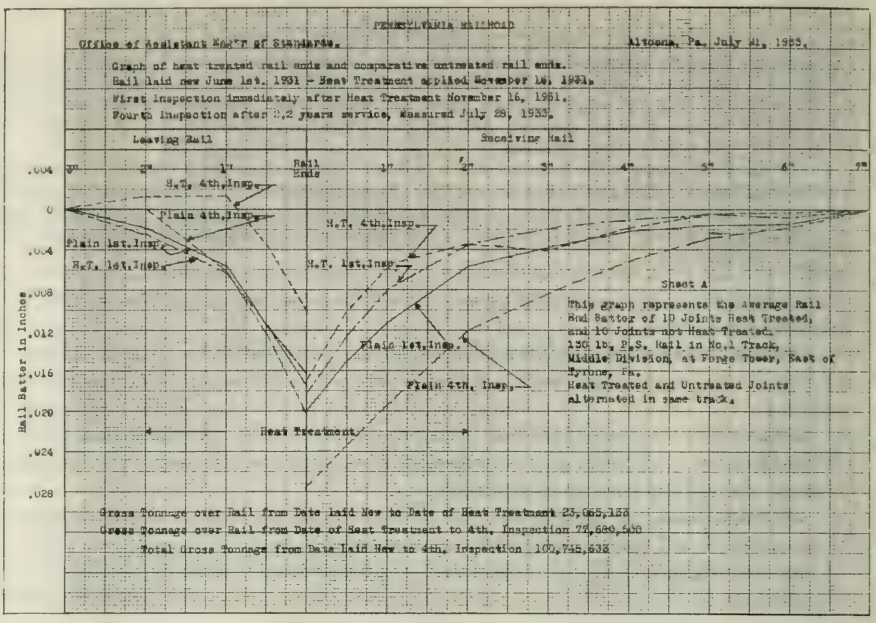


Plate A

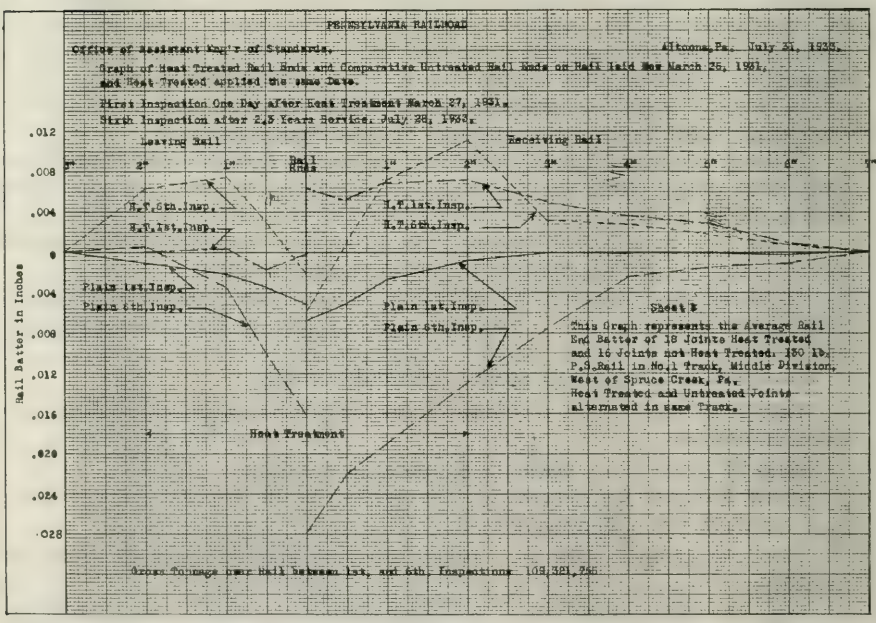


Plate B

the earliest graph shown was from measurements made the day after rail was laid and during which time some batter occurred.

While both of these graphs show the true profile as of date of measurement, it is noted that in the case of the heat treated ends, the rail has apparently raised. This is due to the fact that the straight edge gage used was supported at points 3 in. from the delivering end and 7 in. from the receiving end. Both of these points are outside of the heat treated zone and where the rail received the normal untreated wear leaving the heat treated portion relatively high due to the slower rate of wear on the heat treated areas.

If the heat treated portions become undesirably high, they can be readily ground down at small cost.

Recommendations

In view of the satisfactory experience of heat treating rail ends on the C.M.St.P.&P.R.R., C.&O.Ry., Erie Railroad, and Penna. R.R., also considerable experimental testing on several other roads, where results have been most encouraging, it is recommended that the heat treating of rail ends be generally followed in the case of new rail, cropped rail, or where rail batter has not progressed to an objectionable extent.

It is farther recommended in connection with the above that where necessary the top of rail ends be ground to the same height.

Some of the above mentioned methods of heat treating rail ends have only been available for a short time, and their relative merits and costs are not now known and should be farther studied.

It is urged that extensive tests by railroads generally of the practice of heat treating rail ends be undertaken and that information including results and costs by various methods be made available.

It is recommended that the subject be continued.

Appendix G

(5) ECONOMIC VALUE OF DIFFERENT SIZES OF RAIL

J. M. Farrin, Chairman, Sub-Committee; Lem Adams, J. B. Baker, W. C. Barnes, F. L. C. Bond, R. Faries, C. R. Harding, C. W. Johns, H. C. Mann, G. J. Ray, A. N. Reece, H. R. Thomas, W. P. Wiltsee.

A great deal of work was done on this assignment this year, and percentages derived showing effect of size of rail on the track structure and tentative report prepared but no agreement has been reached upon quantitative value expressed in money to place upon these percentages, so it is considered best to withhold the report for more definite information.

Before final report can be submitted it may be necessary to set aside test tracks made up of the different rails to determine the monetary value of the various percentages.

The Committee therefore reports progress and recommends that the assignment be continued.

Appendix H

(6) RAIL LENGTHS IN EXCESS OF THIRTY-NINE FEET

By R. T. Scholes, Chairman, Sub-Committee

The experience of the Rail Committee at the time the 39-ft. standard length was adopted indicated that it was necessary to negotiate with the committee representing the steel manufacturers in order to study problems or difficulties connected with manufacture and use of the length under consideration. The 39-ft. standard length was generally adopted by the railroads in 1925, and specification providing for same was accepted by the manufacturers without extra charge over the base price.

In taking up consideration of the desirability of adopting a standard length in excess of 39 ft., the Committee has felt that a similar procedure is essential to reach a definite agreement.

Naturally the committee representing the manufacturers desires definite advice as to what the preference of the majority of purchasers is in this respect and also, which is most important to them, whether this standard length would remain undisturbed for a considerable period of time, owing to the fact that the steel companies are confronted with a heavy plant investment in order to furnish longer length rails, and are reluctant to make such investment unless they have assurance that a new standard length is going to remain fixed for some years.

The Committee, in handling this assignment, accordingly undertook to develop the sentiment of various Class I railroads on the subject, and the reports received indicate a preference for standard lengths as follows:

37	roads	favor	39 ft.	standard	length.
9	"	"	45 "	"	"
3	"	"	48 "	"	"
1	"	"	50 "	"	"
5	"	"	66 "	"	"
1	"	"	75 "	"	"
6	"	"	78 "	"	"
1	"	"	79 "	"	"

Total of 63 roads voted to date.

Under the circumstances the Committee feels that it is quite clearly indicated that the majority of railroads are not prepared at this time to present to the manufacturers a request for standard length in excess of 39 ft. It is therefore recommended that the existing standard length be continued for the present. In reaching this conclusion the Committee has in mind the existing business conditions and the undesirability of having the steel companies make heavy plant investments at this time.

The Committee, however, feels as a result of the information received from various railroads as to their experience with rail lengths in excess of 39 ft. that so far as service conditions are concerned, an increased standard length is entirely feasible and practicable and offers considerable promise of improved track and reduced maintenance cost on account of the reduced number of joints to be maintained.

It is highly desirable for the various railroads to continue experiments with long-length rails to obtain further actual service results as a matter of general information to all concerned. The points particularly involved, on which definite information is desired, are as follows:

1. Car supply for handling long rails.
2. Relative cost of loading, unloading and placing in track.
3. Proper expansion allowance.

4. Maintenance of uniform expansion in service.
5. Prevention of rail creeping.
6. Maintenance of line and surface, especially under high temperatures, and prevention of excessive joint gaps under low temperatures.
7. General economy of long-length rails as compared with present 39 ft. standard.
8. Information for each rail mill on changes in plant construction which would be involved if a longer standard length were finally adopted.

The Committee expresses the hope that this experimental work will be continued so that in the course of a few years the railroads will be in a position to unite on a request for a standard length of rail which will be acceptable to a large majority of the railroads of the United States and Canada.

Recommendation

The Committee recommends that this report be received as information and the subject discontinued for the present.

Appendix I

(7) TESTS OF ALLOY AND HEAT TREATED CARBON STEEL RAILS

By W. C. Barnes, Engineer of Tests.

Owing to the small amount of alloy and heat treated carbon steel rail purchased during 1932, no data were presented in last year's report on this subject. The 1933 purchases of these special rails were also very light, but to preserve our record the following data are presented:

ALLOY STEEL RAILS—INTERMEDIATE MANGANESE

Purchases of Intermediate Manganese Rail

Road	*Reported during 1932*	*Reported during 1933*	*Previously Reported*	*Total Tonnages*
A.T. & S.F.	17973	21235	112155	151363
B. & M.			68256	68256
Canadian National			8828	8828
C. & O.			500	500
C.B. & Q.			126550	126550
D. L & W.			106369	106369
K.C.S.			5694	5694
L. & N.			2000	2000
M.K.T.			500	500
N.P.			1705	1705
N.Y.C.			250479	250479
P. R. R.			942	942
Reading			300	300
Illinois Central			5250	5250
S.P.			20344	20344
Southern Ry.			1710	1710
All Roads	17973	21235	711582	750790

Distribution of Intermediate Manganese Rail by Mills

Company	*Plant*	*Currently Reported*	*Previously Reported*	*Total Tonnages*
Algoma	S.S. Marie		5016	5016
Bethlehem	Lackawanna		138767	138767
Bethlehem	Maryland		9742	9742
Bethlehem	Steelton		145039	145039
Carnegie	Edgar Thomson		23714	23714
Colorado	Minnequa	39208	131412	170620
Dominion	Sydney		5838	5838
Illinois	Gary		181610	181610
Inland	Ind. Harbor		61387	61387
Tennessee	Ensley		9057	9057
Totals		39208	711582	750790

A questionnaire was sent to the roads listed in the above tabulation. The following additional data regarding service results obtained with intermediate manganese rail were received from the Atchison, Topeka & Santa Fe; the Boston & Maine; Canadian National; Illinois Central; Kansas City Southern; Missouri–Kansas–Texas; New York Central; Northern Pacific, and Southern Railway.

Question 1—Tonnage purchased during 1932 and 1933 not previously reported:

A.T. & S.F.:—

Year	*Company*	*Plant*	*Wgt. per Yd.*	*Section*	*Tons*
1932	Colorado	Minnequa	110	R.E.	17973
1933	"	"	110	R.E.	20421
1933	"	"	130	R.E.	814

No purchases reported by other roads.

Question 2—Have any changes been made in composition or mill practice for the rails purchased by your railroad during the past two years?

No changes reported.

Question 3—Give results of any special laboratory tests or investigations on new rails that you may have carried out, either in cooperation with the steel mills or in your laboratory.

A.T. & S.F. reports its investigation not yet completed. Other roads report no special tests.

Question 4—Present contours or tabulated results of investigations on wear of rail heads on curves and also tangent track, comparing intermediate manganese with standard open hearth rails in similar service.
What conclusions have you arrived at, based on your general observations of the two classes of steel?

A.T. & S.F.—No contours. No definite conclusion.

Boston & Maine—

Location	Buckland, Mass.		Hoosick Falls, N. Y.				North Pownal, Vt.	
Track	E.B.	E.B.	E.B.	E.B.	E.B.	E.B.	W.B.	W.B.
Degree of Curve	4°–46′	3°–11′	8°–37′	8°–37′	8°–37′	8°–37′	3°–00′	3°–00′
Rail Wgt. & Kind	130C	130MM	130MM	130C	100C	100MM	130C	130MM
Abrasion—Sq. In.								
High Rail	.357	.370	.326	.300	.521	.360	.072	.100
Low Rail	.216	.237	.300	.230	.444	.348	.050	.055
Batter—$\frac{1''}{1000}$								
High Rail	77.5	101.0	101.2	83.8	74.1	59.2	27.2	36.3
Low Rail	86.1	107.5	91.9	94.0	85.2	132.0	35.2	43.0
No. of Chipped Ends	16 of 100	9 of 100	3 of 20	1 of 20	8 of 20	12 of 20	0 of 60	0 of 60
Traffic-Million Gross Tons	72.855	72.855	59.035	59.035	59.035	59.035	20.880	20.880

Location	Buckland, Mass.			Hoosick Falls, N. Y.			North Pownal, Vt.	
Sq. In. Abraded per Million G.T.								
High Rail	.0049	.0051	.0055	.0051	.0088	.0061	.0035	.0048
Low Rail	.0030	.0033	.0052	.0039	.0075	.0059	.0024	.0026
Total Batter— $\frac{1''}{1000}$ per Million G.T.								
High Rail	1.06	1.39	1.71	1.41	1.25	1.00	1.30	1.74
Low Rail	1.18	1.48	1.55	1.58	1.44	2.22	1.68	2.06
Comp. Abrasion 130MM = 100%								
High Rail	97%	100%	100%	92%	160%	110%	72%	100%
Low Rail	91%	100%	100%	75%	136%	113%	91%	100%

Records indicate that medium manganese rails develop batter at a more rapid rate than carbon steel rails. Have had a larger number of split head rails due to segregations.

Illinois Central—We had a small amount of 90-lb. intermediate manganese rail, some of which replaced plain carbon steel rail on a 5 degree curve. Accurate comparison of the wear of the two kinds of steel could not be made as contour measurements had not been taken of the plain carbon rail. We estimate, however, that there was an increase in length of service of the intermediate manganese rail of about 25%.

An excessive number of split heads has developed in some of our intermediate manganese rail indicating that the steel is not of uniform composition. Due to varying traffic, the introduction of track oilers and other causes we are not able to make comparisons of 110-lb. rail.

Kansas City Southern—Measurements continue to show no appreciable difference in wear on inside and outside of a 1° and 5° curve.

Missouri–Kansas–Texas—Inspection in July 1932 showed insufficient wear to warrant conclusions as to relative merits of intermediate manganese and standard O.H. rails.

New York Central—General study of head wear shows that medium manganese rails are resisting abrasion on high side of curves to greater extent than standard open hearth, and also somewhat less flow on low rails of curves.

Southern Railway—Wear in 100 lb. Intermediate Manganese Rail and Standard Carbon Rail installed between Mileposts 710 and 714 near Edwardsville, Ala., Birmingham Division. Rail Installed in May and June 1929 were measured in March 1932.

Section	*Grade*	*Curvature*	*Kind of Rail*	*Per Cent of Head Wear High Rail*	*Per Cent of Head Wear Low Rail*
1– 1	1.25%	6°–58′	IM	5.5%	3.7%
2– 2	1.25%	6°–01′	IM	5.3%	3.4%
3– 3	——	6°–22′	IM	3.2%	3.4%
4– 4	1.25%	4°–27′	IM	4.2%	2.9%
5– 5	1.25%	6°–11′	IM	6.1%	4.2%
6– 6	——	6°–05′	IM	7.4%	6.6%
7– 7	1.25%	4°–55′	Std.	4.2%	1.3%
8– 8	1.25%	6°–05′	"	2.1%	3.7%
9– 9	1.25%	5°–04′	"	5.5%	2.6%
10–10	1.10%	5°–59′	"	5.0%	3.7%
11–11	1.50%	5°–51′	"	5.3%	2.4%
12–12	——	6°–07′	"	6.6%	1.6%

The information obtained tends to indicate that intermediate manganese rail wears more rapidly than our standard steel rail.

Question 5—Present general or specific data on the batter and chipping of rail ends, comparing intermediate manganese and standard open hearth rails.

A.T. & S.F.—After five years under similar conditions, Intermediate manganese rail shows 1.7 per cent of chipping against 15 per cent for standard open hearth. Rail batter approximately the same on both.

New York Central—There is no noticeable difference in batter or chipping as shown by general observations.

Boston & Maine—See answer to Question 4.

Illinois Central—No difference with respect to chipping has been observed.

Canadian National—No definite conclusions yet.

Question 6—Table of Intermediate Manganese Rail Failures, summarizing total failures since rail was laid, to January 1, 1933.

Year Rolled	*Mill*	*Section*	*Tons Rolled*	*Trans. Fiss.*	*Compd. Fract.*	*H. Split Head*	*V. Split Head*	*Crushed Head*	*Web*	*Base*	*Angular*	*Broken*	*Misc.*	*Total*
						A.T. & S.F.								
1926	Inland	110RE	3113	—	—	1	2	—	4	—	—	—	—	7
1928	Colo.	90AT	966	—	—	—	—	—	—	—	—	—	—	—
1928	Colo.	110RE	20079	—	—	4	24	—	—	—	—	—	—	28
1929	Colo.	110RE	40659	—	—	2	9	5	—	—	—	—	—	16
1930	Colo.	110RE	47949	—	—	1	1	1	—	1	—	—	—	4
1932	Colo.	110RE	17973	—	—	—	2	—	—	—	—	—	—	2
						Boston & Maine								
1927	Stltn	100NH	3153	—	—	—	3	2	6	—	6	—	—	17
1928	Stltn	100NH	12147	—	—	—	38	11	1	32	20	—	—	102
											(3 heats removed)			
1929	Stltn	100NH	4555	—	—	—	1	1	1	—	1	—	—	4
1929	Stltn	130RE	28044	1	—	—	302	9	2	—	3	—	—	317
											(3 heats removed)			
1930	Stltn	130RE	6358	—	—	—	—	—	—	—	—	—	—	—
											(change of Spec.)			
						Canadian National								
1929	Sydney	85HF	1359.4	—	—	—	169	1	8	—	—	—	—	178
1929	Alg.	100HF	1591.4	2	1	—	201	1	—	1	—	—	14	220
1930	Sydney	85HF	2687.1	—	—	—	6	—	—	—	—	—	—	6
1930	Alg.	100HF	3192.9	—	—	—	9	—	—	—	—	—	—	9
						Illinois Central								
1929	Gary	110RE	1060	—	—	—	13	—	5	—	—	2	—	20
1930	Gary	110RE	1398	1	—	—	11	—	3	—	—	—	—	15
1930	Inland	110RE	2428	—	—	—	—	—	—	—	—	—	—	—
						Kansas City Southern								
1926	Beth.	100RE	540	—	—	—	—	1	2	—	—	—	—	3
1928	Beth.	127 Dud	1302	—	—	—	—	—	1	—	—	—	—	1
1928	Carn.	115 Dud	840	—	—	—	2	—	—	—	—	—	—	2
1929	Beth.	100RE	760	—	—	—	1	—	1	—	—	—	—	2
1929	Ill.	100RE	930	—	—	—	—	—	—	—	—	—	—	—
1929	Inland	127 Dud	959	—	—	—	—	—	—	—	—	—	—	—
1930	Beth.	127 Dud	360	—	—	—	—	—	—	—	—	—	—	—
						Missouri–Kansas–Texas								
1929	Gary	90RA-A	250	1	—	—	—	—	—	—	—	—	—	1
1929	Ensley	90RA-A	250	—	—	—	—	—	—	—	—	—	—	—
						Southern Railway								
1929	Ensley	100RE	1710	10	2	—	28	12	—	—	—	1	—	53

Northern Pacific

Year Rolled	*Mill*	*Section*	*Tons Rolled*	*Broken Head*	*Web*	*Base*	*Total*	*Spec. Min. & Max. Carbon*
1926	Gary	100RE	953	4	41	—	1	46	50–65
1926	Gary	130RE	752	1	19	—	—	21	55–70
1926	Gary	100RE	19779	30	88	—	5	123	62–77
1926	Gary	130RE	1408	37	13	—	—	50	72–89

NEW YORK CENTRAL LINES

MEDIUM MANGANESE RAIL FAILURES
CUMULATIVE TOTALS TO JANUARY 1, 1933

Road	Mill	Sect.	Rolled	Tons Shipped	Miles Track	ITF	Other Breaks	Split Heads	Crushed Heads	Web	Base	Total
N. Y. C. East	Lack.	127#	1926	4,590	22.9	22	3	37	128	5	-	195
" "	"	"	1927	2,476	12.4	7	-	4	39	1	-	51
" "	"	"	1928	14,503	72.6	6	-	16	38	3	-	63
" "	"	"	1929	34,757	173.5	14	4	23	229	5	3	278
" "	"	"	1930	55	0.3	-	-	-	-	-	-	-
" "	"	"	1931	5,000	25.0	-	-	-	1	-	1	2
" "	"	105#	1925	1,367	8.3	3½	-	-	23	2	-	56
" "	"	"	1926	3,033	18.4	36	-	1	21	1	-	59
" "	"	"	1927	2,281	13.8	2	-	3	7	-	2	14
" "	"	"	1928	12,904	78.0	3	1	6	11	1	1	23
" "	"	"	1929	5,081	30.8	-	-	-	-	3	1	4
" "	"	"	1930	1,158	7.0	-	-	-	-	-	-	-
N. Y. C. West	"	127#	1928	2,591	12.9	-	-	1	2	-	-	3
" "	"	"	1929	5,824	29.2	1	1	3	60	-	-	65
" "	"	"	1930	1,664	8.3	-	-	-	-	-	-	-
" "	Gary	"	1926	3,431	17.2	6	1	21	85	2	-	115
" "	"	"	1927	7,974	39.8	2	1	11	38	1	-	53
" "	"	"	1928	19,163	95.9	1	-	7	4	2	-	14
" "	"	"	1929	20,206	101.0	-	-	8	3	1	-	12
" "	"	"	1930	13,139	65.7	-	1	3	2	-	-	6
" "	Inland	"	1930	3,139	15.7	-	-	-	-	-	-	-
" "	Gary	105#	1926	1,475	8.9	2	-	5	7	-	-	14
B. and A.	Lack.	105#	1926	975	5.9	6	-	11	5	2	-	24
"	"	"	1927	1,004	6.1	15	-	5	5	1	-	26
"	"	"	1929	1,627	9.9	1	-	24	-	-	-	25
P. and L. E.	Carnegie	115#	1926	1,001	5.5	-	-	10	2	-	-	12
"	"	"	1927	2,667	14.7	1	-	4	-	-	-	5
"	"	"	1928	2,957	16.3	-	-	-	4	1	-	5
"	"	"	1929	1,872	10.3	-	-	-	2	½	-	2
"	"	"	1930	1,287	7.2	-	-	-	-	-	-	-
C.C.C.& St. L.	Gary	127#	1929	12,506	62.5	-	-	15	1	2	-	19
"	Inland	"	1929	6,585	32.9	-	-	6	-	1	-	7
"	Carnegie	"	1929	10,901	54.5	-	-	2	-	-	-	2
"	Gary	105#	1926	2,188	13.3	15	-	17	62	3	-	97
"	"	"	1927	166	1.0	3	-	-	1	2	-	6
"	Inland	"	1928	407	2.5	-	-	-	-	-	-	-
Mich. Cent.	Gary	127#	1929	1,569	7.8	-	-	1	-	-	-	1
"	"	"	1930	4,600	23.0	-	-	-	1	-	-	1
"	Dominion	"	1929	100	0.5	-	-	1	-	-	-	1
"	"	"	1930	1,196	6.0	-	-	-	-	-	-	-
"	Inland	105#	1929	1,797	10.9	-	-	-	-	-	-	-
NYC - OCL	Gary	127#	1930	2,001	10.0	-	-	-	-	1	-	1
"	"	105#	1928	5,000	30.3	-	-	2	1	2	-	5
"	"	"	1929	4,008	24.3	-	-	2	-	-	-	2
"	"	"	1930	1,997	12.1	-	-	-	-	-	-	-

NEW YORK CENTRAL LINES

DETECTED MEDIUM MANGANESE RAILS

CUMULATIVE TOTAL TO JANUARY 1, 1933

Road	Mill	Sect.	Rolled	Tons Shipped	Miles Track	ITF	Other Breaks	Split Heads	Crushed Heads	Web	Base	Total
N. Y. C. East	Lack.	127#	1926	4,590	22.9	21	-	1	6	-	-	28
"	"	"	1927	2,476	12.4	6	-	7	14	-	-	27
"	"	"	1928	14,503	72.6	2	-	2	1	-	-	5
"	"	"	1929	34,757	173.5	24	-	5	27	-	-	56
"	"	"	1930	55	0.3	-	-	-	-	-	-	-
"	"	"	1931	5,000	25.0	1	-	-	-	-	-	1
"	"	105#	1925	1,367	8.3	-	-	-	-	-	-	-
"	"	"	1926	3,033	18.4	-	-	-	-	-	-	-
"	"	"	1927	2,281	13.8	-	-	-	-	-	-	-
"	"	"	1928	12904	78.0	6	-	-	13	-	-	19
"	"	"	1929	5,081	30.8	-	-	-	1	-	-	1
"	"	"	1930	1,158	7.0	-	-	-	-	-	-	-
N. Y. C. West	Lack.	127#	1928	2,591	12.9	-	-	2	-	-	-	2
"	"	"	1929	5,824	29.2	2	-	1	4	-	-	7
"	"	"	1930	1,664	8.3	-	-	-	-	-	-	-
"	Gary	"	1926	3,431	17.2	6	-	5	13	-	-	24
"	"	"	1927	7,974	39.8	2	-	6	1	-	-	9
"	"	"	1928	19,163	95.9	1	-	1	-	-	-	2
"	"	"	1929	20,206	101.0	-	-	2	2	-	-	4
"	"	"	1930	13,139	65.7	-	-	2	-	-	-	2
"	Inland	"	1930	3,139	15.7	-	-	-	-	-	-	-
"	Gary	105#	1926	1,475	8.9	-	-	-	-	-	-	-
B. and A.	Lack.	105#	1926	975	5.9	-	-	-	2	-	-	2
"	"	"	1927	1,004	6.1	5	-	3	1	-	-	9
"	"	"	1929	1,627	9.9	3	-	1	2	-	-	6
P. and L. E.	Carnegie	115#	1926	1,001	5.5	-	-	-	-	-	-	-
"	"	"	1927	2,667	14.7	-	-	-	-	-	-	-
"	"	"	1928	2,957	16.3	-	-	-	-	-	-	-
"	"	"	1929	1,872	10.3	-	-	-	-	-	-	-
"	"	"	1930	1,287	7.2	-	-	-	-	-	-	-
C.C.C.& St. L.	Gary	127#	1929	12,606	62.5	-	-	7	-	-	-	7
"	Inland	"	1929	6,585	32.9	-	-	-	-	-	-	-
"	Carnegie	"	1929	10,901	54.5	-	-	1	2	-	-	3
"	Gary	105#	1926	2,188	13.3	32	-	7	13	-	-	52
"	"	"	1927	166	1.0	20	-	-	3	-	-	23
"	Inland	"	1928	407	2.5	-	-	-	-	-	-	-
Mich. Cent.	Gary	127#	1929	1,569	7.8	-	-	-	-	-	-	-
"	"	"	1930	4,600	23.0	-	-	-	-	-	-	-
"	Dominion	"	1929	100	0.5	-	-	-	-	-	-	-
"	"	"	1930	1,196	6.0	-	-	-	-	-	-	-
"	Inland	105#	1929	1,797	10.9	-	-	-	-	-	-	-
NYC - OCL	Gary	127#	1930	2,001	10.0	-	-	-	-	-	-	-
"	"	105#	1928	5,000	30.3	-	-	-	-	-	-	-
"	"	"	1929	4,008	24.3	-	-	-	-	-	-	-
"	"	"	1930	1,997	12.1	-	-	-	-	-	-	-

Question 7—How do intermediate manganese and standard open-hearth rail failures compare, giving detailed statement, or general conclusions.

A.T. & S.F.

Data similar to that for Question 6 is here given for standard open-hearth rail.

Year Rolled	*Mill*	*Section*	*Tons Rolled*	*Trans. Fiss.*	*Compd. Fract.*	*H. Split Head*	*V. Split Head*	*Crushed Head*	*Web*	*Base*	*Total*
1926	Inland	110RE	11350	11	2	0	9	2	0	1	25
1928	Colo.	110RE	45076	5	0	5	2	1	1	1	15
1929	Colo.	110RE	65050	0	0	3	1	0	0	1	5
1930	Colo.	110RE	3574	0	0	1	3	2	0	0	6
1932	Colo.	110RE	11727	0	0	0	0	0	0	0	0

Have had no transverse fissure failures in intermediate manganese rail to date.

Boston & Maine

In the years 1927, 1928, 1929 and 1930, 48360 tons of standard open hearth carbon rails were purchased. The failures in this type of rail to January 1, 1933 have been less than .15 per cent. The failures in the 100-lb. intermediate manganese have been approximately .40 per cent and in the 130-lb. intermediate manganese approximately .70 per cent.

Canadian National

The following shows comparative failures in intermediate and carbon steel rails which have been in track approximately the same time.

			Average rate of failure per 100 track miles per year
85-lb. H.F. Inter. Mang.	rolled	1929	523
85-lb. H.F. Carbon Steel	"	"	10
85-lb. H.F. Inter. Mang.	"	1930	23
85-lb. H.F. Carbon Steel	"	"	12
100-lb. H.F. Inter. Mang.	"	1929	655
100-lb. H.F. Carbon Steel	"	"	21
100-lb. H.F. Inter. Mang.	"	1930	20
100-lb. H.F. Carbon Steel	"	"	18

Illinois Central

Comparison of Rail Failures of I.M. rail and Plain Carbon steel rail.

Year Rolled	*Mill*	*Kind of Steel*	*Weight and Section*	*Track Miles Laid*	*Failures per 100 track miles per year in service*
1929	Gary	I M	110 RE	6.13	111.1
1930	Gary	I M	110 RE	8.09	93.7
1930	Inland	I M	110 RE	14.05	00.0
1929	Gary	O H	110 RE	8.29	4.1
1930	Gary	O H	110 RE	13.85	3.7
1930	Inland	O H	110 RE	23.22	00.0

Kansas City Southern

For all intermediate manganese rail in track the failures to January 1, 1933 average one failure per 3270 ton-years in service. Open-hearth rail laid in the same years show one failure per 17000 ton years. It should be remembered, however, that the intermediate manganese rail was all laid on curves of two degrees and over, which should be taken into consideration in comparison of failures.

Northern Pacific

Owing to the presence of horizontal split heads in intermediate manganese rail, the failure rate seems somewhat excessive. In the comparative statement under Question 6 a very large proportion of the broken standard composition rails broke in a long tunnel through the bolt holes and where this is taken into consideration the showing of the intermediate manganese 130 lb. compared with the standard rail would be as unfavorable to the former as it is in the case of the 100 lb. section.

New York Central

In comparing rail failures in medium manganese with open hearth rails, the general statement applies that fissures are considerably less numerous in medium manganese rails than in standard open hearth rails. Head failures in the former are very much higher, of which 75 per cent or more are horizontal crushed or split heads in the receiving end of the rail, usually about ½ inch deep by 2 inches lengthwise of the head, due largely to internal shattering, plus the pounding which the rail ends are subject to.

Southern Railway

Transverse and compound fissures occurring in all rail of 1929 rolling prior to January 1, 1933, show a rate of 7.02 per 1000 tons for intermediate manganese against 0.32 per 1000 tons for carbon rail. The record of all failures in the same rail show a rate to January 1, 1933, of 31.0 per 1000 tons of intermediate manganese rail against 0.88 per 1000 tons of carbon rail.

Question 8—Report special tests or investigations on failed or defective intermediate manganese rails, and conclusions derived therefrom.

A.T. & S.F.—Investigation not yet completed.

New York Central—Any investigations which we have made recently on defective medium manganese rails show the same results as previously reported, that is, high physical properties, general freedom from segregation, and finer grain structure than is obtained usually in standard open hearth rails.

Question 9—What conclusions, briefly stated, have you arrived at as to the relative merits of intermediate manganese compared to standard open hearth rails.

A.T. & S.F.—See Question 4.

Boston & Maine—We do not plan to purchase any more medium manganese rails due to the fact that our records indicate that medium manganese rails develop batter at a more rapid rate than carbon steel rails and the further fact that we have had a large number of split head rails due to segregation.

Illinois Central—See Question 4.

Canadian National & Kansas City Southern—No conclusions have been made as yet.

Missouri Kansas Texas—See Question 4.

Northern Pacific—We do not believe that the very slight if any improvement in wearing qualities and resistance to batter in the intermediate manganese rail would compensate for the large increase in horizontal split heads. It is possible, however, that revised specifications for manganese and carbon might so reduce the appearance of horizontal split heads that this objection would be overcome.

New York Central—Medium manganese rails have invariably shown better properties and structural condition than standard open hearth rails, but the steel as commercially handled at the present and in the past has been prone to shattering which has developed considerable number of head failures of the horizontal crushed or split type.

Southern—We very much prefer open-hearth rail to intermediate manganese rail.

Heat Treated Steel Rails

QUESTIONNAIRE ON HEAT TREATED RAILS

1. Rails purchased during 1932 and 1933 not previously reported, giving following details:—

COMPANY PLANT NO. RAILS LENGTH ROLLED WEIGHT SECTION

2. Report results of special tests on new rails, comparing treated versus untreated.
3. Present contours or tabulated results of investigations on wear of rail heads, comparing treated and untreated rails, giving details of curvature, tonnage, age of rail, etc.
4. Present general or specific data on batter and chipping of rail ends, comparing treated and untreated rails.
5. Itemized list of any rail failures.
6. Report results of investigations on any failed heat treated rails.
7. What conclusions, briefly stated, have you arrived at of the relative merits of treated compared to untreated rails?

The purchase of heat treated rail during 1932 and 1933 were very light. They consisted of 300 tons of 100 lb. A.R.A.–B rail in 1932, a like amount in 1933 by the Interborough Rapid Transit Company of New York and 120 tons by the New York Rapid Transit Company in 1932 from the Bethlehem Steel Company and 160.6 tons of 130 lb. rail by the Norfolk & Western in 1932 and 161.1 tons of 130 lb. rail by the Erie Railroad in 1933, from Carnegie Steel Company. The Bethlehem rail was made by their so called "Lead Bath" process and the Carnegie rail by the "controlled cooling" process.

The following data was received in reply to the questionnaire:

Boston & Maine

Location	Buckland, Mass.		Hoosick Falls, N.Y.	
Track	E.B.	E.B.	E.B.	E.B.
Degree of Curve	4°–24′	4°–46′	8°–37′	8°–37′
Rail Wgt. & Kind	130CHT	130C	130C	130CHT
Abrasion—Sq. In.				
High Rail	.188	.357	.300	.276
Low Rail	.120	.216	.230	.213
Batter—$\frac{1''}{1000}$				
High Rail	67.6	77.5	83.8	68.6
Low Rail	80.0	86.1	94.0	83.2
No. of Chipped Ends	10 of 100	16 of 100	1 of 20	0 of 20
Traffic–Million Gross Tons	72.855	72.855	59.035	59.035
Sq. In. Abraded per Million G.T.				
High Rail	.0026	.0049	.0051	.0047
Low Rail	.0016	.0030	.0039	.0036
Total Batter—$\frac{1''}{1000}$ per Million G.T.				
High Rail	0.93	1.06	1.41	1.16
Low Rail	1.11	1.18	1.58	1.40
Comp. Abrasion 130MM—100 per cent				
High Rail	51 per cent	97 per cent	92 per cent	85 per cent
Low Rail	51 per cent	91 per cent	75 per cent	69 per cent

No rail failures reported. Our experience thus far has indicated that heat treated rail is giving us much better service than ordinary carbon rail. Our tests, however, have not been conducted long enough to permit definite recommendation. Our experience in the use of heat treated rail in crossing frogs indicates a marked superiority over solid manganese.

Baltimore & Ohio Railroad

	Test No. 974 Treated Rail	*Test No. 973 Untreated Rail*
Installed	March, 1929	March, 1929
Number of Rails in test	30	14
Degree of curve	10°	10°
Elevation	3″	3″
Speed limit	20 M.P.H.	20 M.P.H.
Tonnage	54,190,000	54,190,000
Average area abraded, high rails	0.400 Sq. In.	0.797 Sq. In.
" " " low "	0.207 Sq. In.	0.283 Sq. In.
Carbon content	0.72–0.89	0.77–0.84
Manganese content	0.50–0.90	0.55–0.75
Phosphorus content	0.04	0.04
Silicon content	0.15	0.15
Rate of Wear	100%	178%
Age in track	53 months	53 months

Batter Measurements

	Heat Treated	*Untreated*
Batter starts, leaving end	5″	5⅝″
Batter at ½″ leav. end (in thousandths)	10	10
Batter at leaving end " "	20	25
Batter at receiving end (in thousandths)	22	25
Batter at ½″ from rec. end (in thousandths)	13	15
Batter stops at rec. end	4″	5½″
Joint gap (average)	15/64″	5/64″
Spalls	9	7
Rails in test	30	14
Per cent of spalled ends	15%	25%

Rail Failures—No failures

Conclusions

The heat treated rails, due to increased toughness, are abraded to a lesser extent than the untreated, the ratio being 1. to 1.78.

The batter both in length and intensity at the rail ends is slightly greater on the untreated rails.

The Chesapeake and Ohio Railway Company

QUESTIONNAIRE ON HEAT TREATED RAIL—BETHLEHEM "LEAD BATH" PROCESS

1. Rails purchased during 1932 and 1933 not previously reported, giving following details:'

Company	*Plant*	*No. Rails*	*Length*	*Rolled*	*Weight*	*Section*
A—Beth. Steel Co.	Steelton	1249	39′	11—1931	130	RE
		42	37′			
		1	36′			
		2	35′			
		27	34′			
		2	33′			
		6	32′			
		1	31′			
		4	29′			
		1	28′			
		1335				

A small portion of this rail was purchased during 1930 and the balance in 1931, making a total of 1000 tons.

2. Report results of special tests on new rails, comparing treated versus untreated.

A—This rail has been laid at two locations, approximately 500 tons at each point. The first location is on the Marion District, Westbound track M.P. 32.11 to 36.49, laid January 1932. A small portion is on a curve at the east end but by far the largest part is on a tangent. The rail has shown very little wear at this point after 21 months of service under heavy coal traffic. The batter has been so small that it is hardly possible to measure.

The other 500 tons was laid on the Rivanna District, M.P. 102.17 to 104.88, during August 1931 and August 1932. The east end of this rail was laid alternately with common open hearth rail. This method was followed in order to obtain a direct comparison of the two types of rail.

General Condition of Test Rails: The common O.H. rail on the tangent test track was in good condition but on the curved track the ends of the rail were of a poor appearance, some chipped, some ragged or frayed at the end of the running surface. Almost without exception the Heat Treated rail was in fine condition and to the eye most of the rail ends were clean and new in appearance. The column "Percent Chipped" in attached table does not tell the whole story for where many of the common rails had large prominent chips, chipping on the Heat Treated rails was of a minor nature, there being no really noticeable chipped rail ends.

3. Present contours or tabulated results of investigations on wear of rail heads, comparing treated and untreated rails, giving details of curvature, tonnage, age of rail, etc.

A—This information included in table presented under question 4.

4. Present general or specific data on batter and chipping of rail ends, comparing treated and untreated rails.

A—A record of measurements was made on the test rails and of general information bearing on the study. The following points are explanatory and an extension of information obtained.

Description of Location	Group Number	No. of Joints Still in Test 10-4-33	No. of Jts. Built Up Since Rail was Laid	Date Laid	Gross Tons Traffic Through Sept.30.1933	Condition of Rail Ends Oct. 4, 1933 — Average Batter: East End Rec.Rail	West End Leav.Rail	Avg. End	% Chipped	Ave. Size of Gap
Tangent	1-a (H.T.)	17	0	Aug. 1931	54,404,480	0.0109"	0.0088"	0.0087"	29.4%	0.0522"
	1-b (Common)	15	2	Mar. 1931	66,442,068	0.0185"	0.0101"	0.0490"	93.3%	0.0520"
Half of each tangent: Other half is high rail at 4°-30' curve	2-a (H.T.)	* 20	0	Aug. 1931	54,404,480	0.0157"	0.0089"	0.0510"	40.0"	0.1156"
	2-b (Common)	15	5	Mar. 1931	66,442,068	0.0260"	0.0172"	0.0980"	73.3%	0.0531"
Low Rail of 3°30' curve	3-a (H.T.)	** 7	0	Aug. 1932	29,355,710	0.0140"	0.0069"	0.0133"	0.0%	0.0914"
	3-b (Common)	7	0	Aug. 1932	29,355,710	0.0094"	0.0103"	0.0580"	57.1%	0.0534"
Half of each tangent: other half is low rail of 4°-30' curve	4-a (H.T.)	22	0	Aug. 1931	54,404,480	0.0142"	0.0097"	0.0261"	18.2%	0.0909"
	4-b (Common	* 13	7	Mar. 1931	66,442,068	0.0160"	0.0168"	0.0468"	92.3%	0.0660
High Rail at 3°30' curve	5-a (H.T.)	6	0	Aug. 1932	29,355,710	0.0142"	0.0075"	0.0345"	66.7%	0.0553
	5-b (Common)	** 7	0	Aug. 1932	29,355,710	0.0103"	0.0098"	0.0827"	42.9%	0.1271"
Total	Heat Treated	72	0	Oct. 1931	Av.49,881,786	Av.0.0136"	0.0088"	0.0283"	29.17%	0.0866"
	Common O.H.	57	14	July 1931	Av.57,331,138	" 0.0177"	0.0134"	0.0666"	77.19%	0.0549"

* One less joint included in Average Batter on Leaving Rail)
** One more joint included in Average Batter on Receiving ")

NOTE: Track under test has traffic in both directions but E.B. traffic is approximately three times W.B. therefore the west rail of joint is considered the leaving end and the east rail receiving. Built up joints are omitted from test data.

1. The grouping (1-a, 1-b. 2-a, etc.), was intended for comparing the two types of rails on tangents, on high side of curves, and on low side of curves. Possibly the 3 and 4 groups do not contain sufficient number of rails for a conclusive test at their particular location. More will develop as the study continues.

2. Of 57 common rails laid in March 1931, fourteen battered and chipped to such an extent that they had to be built up by welding. These welded joints constitute 24.6 per cent of the original total of groups 1-b, 2-b and 4-b. As of October 4, 1933, none of the heat treated rail had been rebuilt, and none needed to be rebuilt, but even though almost a fourth of the common rail had already been rebuilt there were several more of the same rail battered and chipped sufficient to need welding.

3. End flow is interesting as a matter of record but actually it is not of great importance in a study of this type. It is probably very much dependent on such extraneous factors as the amount of uniformity there is in joint bolt tightness and the snugness of rail anchors. For instance suppose there is play enough between anchors and ties to allow the expansion of three rails to be taken care of at one joint and assume that two sets of joint bars are tightly bolted and one not near so tight. Then all the expansion will be released at the loose joint, the flowed lip at that joint will be mashed or broken off, and the other two joints undisturbed.

5. Itemized List of Rail Failures.

A—	*Heat No.*	*Letter*	*Ingot*	*Date*		*Type*			*District*
	81354	D	4	11–1932		Trans.	Fiss.		Marion
	83335	B	1	5–1933		"	"		Rivanna
	83348	D	9	2–1932		"	"		Marion
		C	9	11–1932		"	"		"
*		E	13	3–4–32		"	"	60%	"
*		D	2	"		"	"	55%	"
*		D	13	"		"	"	50%	"
*		E	11	"		"	"	Crack	"
*		C	3	"		"	"	"	"
*		E	6	3–5–32		"	"	70%	"
*		C	13	"		"	"	75%	"
	83350	D	14	2–1932		"	"		"
*		E	11	3–5–32		"	"	15%	"
	86344	C	13	8–1932		"	"		Rivanna
	86361	C	10	2–1932		"	"		Marion
*		B	10	3–4–32		"	"	Crack	"
*		C	9	3–5–32	2	"	"	60% 85%	"
*		B	9	"		"	"	65%	"
*		D	10	1–10–33		"	"	50%	"
*		E	10	"		Fracture	Cracks		"

* Rails marked thus were found by Sperry Car.

Rail 86344—C—13 failed after two weeks service in track.

Rails 83348—D—9, 83350—D—14 and 86361—D—10, failed on February 12th, 16th and 29th, 1932, respectively. This rail was laid during the first and second weeks of January 1932.

6. Report results of investigations on any failed heat treated rails.

A—The 11 rails found by Sperry car in 1932 and the three rails mentioned in the latter part of paragraph five were studied and the following report submitted:

The rails were put through the roller tests at 5/8" deflection in 60 inches which ruptured all rails but 83348—G—3 and 83350—E—11.

An unusual feature of these ruptures is their size; in most cases the greater part of the head was ruptured, and the appearance convinced us that this had happened before the rails were annealed. While these ruptures are extremely large in size, we have not been able to find any trace of shatter cracks in any of these rails, although search was made by hot acid etching twice the usual amount of mid section of the head.

Brinell hardness determinations at various parts of the section show somewhat greater hardness than we usually get from this rail section. (The diagrams accompany-

ing the original report have been omitted. They show the following Brinell hardness limits:

In two rails, heat 83350, Brinell minimum 293, Maximum 402
In four rails, heat 86361, Brinell minimum 311, Maximum 430
In seven rails, heat 83348, Brinell minimum 340, Maximum 418

A thorough investigation of the open hearth history convinces us that the steel quality is not responsible. We have the impression that the quench may have been more severe than usual. This might result from colder water or a delayed quench. If the rails were delayed in getting into the water, the standard time of quenching might cool the rail into the blue brittle temperature. We are working on means to guard against this in the future.

Rail 86344—C—13 was also studied and the following report submitted:

The broken rail has been received and examined with following results:

Rail was C–13 from heat 86L344 rolled in Nov. 1931.

Analyses of ladle and rail show—

	C	*Mn*	*P*	*S*	*Si*
Ladle	.750	.74	0.21	0.29	.18
O	.780	.74	.024		
Rail M	.783	.74	.027		

Rail was broken about 6 ft. from end and the long piece was put through the roller bending machine with no other breakage. The rail was then beheaded and the head sent to the frog shop where it was bent in a hydraulic machine with no failures resulting. This was a most searching test, the rail head being bent to 45° in some of the thrusts of the ram without breaking and it was necessary to reverse the bend in order to obtain a fracture. All the fractures were clear and no evidence of heat cracks were found.

A cross section of the rail head adjoining the track break was polished and readings with Rockwell and Brinell hardness machines taken. The Brinell hardness varied between 351 and 387 and the Rockwell hardness, Scale C, between 33 and 42.

A cross section of rail head immediately back of the track break was given a hot acid deep etch which disclosed a slight sponginess in the upper center of the web; the head was fairly free from segregation and inclusions.

A close examination of the broken faces of the rail gave no clue as to the actual cause of failure. There were no indications of quenching cracks nor were the familiar features of transverse fissures to be seen, in fact, we inclined to the belief that the break started in the base, due to the appearance of the fracture in that location, but as no sign of a seam could be discovered the theory was impotent.

7. What conclusions, briefly stated, have you arrived at of the relative merits of treated compared to untreated rails?

A—It is believed that this rail has not been in track long enough for a definite conclusion to be found regarding its serviceability.

Interborough Rapid Transit Company (N.Y.)

During 1932 we purchased 300 tons of 100-lb. ARA–B section heat treated rails, 33′ long, from the Bethlehem Steel Company. They were rolled at that company's Steelton plant during February.

We purchased from the same company during 1933, 300 tons of 100-lb. ARA–B section heat treated rails, 33′ long. This rail was rolled at that company's Steelton plant during June. The rail is laid on curves of 200′ to 800′ radius.

Service records consistently show that the ratio of wear of heat treated rail in our specification carbon (.78 to .93) open hearth steel rail is approximately 0.50.

No heat treated rails furnished during 1932 and 1933 have failed to date.

Lehigh Valley Railroad

In regard to heat treated rails, I would advise that we have not purchased any heat treated rails on this railroad, but were given fifty (50) in connection with our regular rail purchases by Bethlehem Steel Company from their Steelton Plant, in 1928,

these rails being 39 ft. long, 136 lb. per yard. These rails were placed in track in October 1928, 25 being installed on a 13 degree curve and the remaining 25 on a 10 degree curve. Comparative measurements were made from time to time with the high carbon rail in the same curve, the latter rail running about .84 carbon. In November 1929 the rails on both curves were transposed on account of lateral wear on the high rail, and from observation and also measurements, very little difference could be noticed as between the heat treated and the high carbon rail. Furthermore, I could see no great difference in the batter or chipping of the ends. We had no rail failures.

In my opinion from our experience with the heat treated rail furnished in 1928, I do not believe it gives sufficiently better results to warrant the additional price, which I understand is approximately $20.00 per gross ton in excess of the regular rail price.

New York Central Lines

1. No purchases in 1932 and 1933, excepting a lot of 82 rails of the 127 lb. Dudley section, which comprises normalized, box cooled, and rails of standard treatment for comparison. These have only recently been laid in service.

2. The above mentioned rails were rolled by the Illinois Steel—Gary Works in December 1932 and June 1933 and are all 39 ft. long.

3. On previously reported heat treated rails, the general observation shows that there is only slight superiority on the high side, and a very marked superiority on the low side of curves for heat treated rails over those untreated, in comparative test locations.

4. No noticeable difference in chipping. As to batter, the heat treated rails on the low side of curves are very markedly less battered than the untreated rails.

5. No rail failures have occurred, excepting the two previously reported in the 115 lb. Dudley treated rails on the P. & L.E. shortly after installation.

6. No reports on failed treated rails.

7. The only point of difference or superiority for the heat treated rails so far is found in the lesser flow of the low rails on curves, coupled with lesser batter on these rails.

Appendix J

(8) REDESIGN RAIL SECTIONS HEAVIER THAN 100 LB. PER YARD SO AS TO OBTAIN THE MOST ECONOMICAL DISTRIBUTION OF METAL WITH THE MAXIMUM STRENGTH OF SECTION

G. W. Harris, Chairman, Sub-Committee; J. E. Armstrong, W. C. Barnes, A. F. Blaess, N. J. Boughton, C. T. Dike, J. M. Farrin, L. C. Fritch, C. R. Harding, W. H. Kirkbride, H. C. Mann, W. H. Penfield, W. H. Petersen, A. N. Reece, R. T. Scholes, J. R. Watt, Louis Yager.

As demand was made for the early adoption of a revised rail section whose weight would lie between that of the 131-lb. RE section adopted at the 1933 Convention and the present standard 100-lb. RE section, a section weighing 112-lb. per yard was developed and recommended by the Rail Committee for adoption as standard in place of the 110-lb. RE section.

Action on the Committee's recommendation could not be delayed until the following Convention and it was therefore submitted to the Association by letter-ballot dated July 1, 1933, and the recommendations were approved by a large majority vote. As a matter of record the form of the letter-ballot and result of the vote are given below.

This report is submitted as information.

American Railway Engineering Association

LETTER-BALLOT ON 112-LB. RE RAIL SECTION

Chicago, July 1, 1933.

To the Members:

Since the Annual Meeting in March, the Committee on Rail has been engaged on a revision of the 110-lb. RE Rail Section, shown on page 143 of the 1929 Manual.

A revised section was presented and approved at a recent meeting of the Committee on Rail. On following pages the general principles governing the design and the properties of the new 112-lb. RE Rail Section; argument in support of the recommendation for its approval, and an illustration of the revised section, are set forth.

In order that Railway Companies may have the benefit of the new standard and place rail orders therefor promptly, the Board of Direction has directed that the revised section be submitted to the membership for approval by letter-ballot.

In the event that a majority of the members voting approve the revised section, it will be presented to the Board of Directors of the American Railway Association for endorsement and approval.

Please indicate your vote on attached coupon and return it to the Secretary's office not later than July 29, 1933.

E. H. Fritch, *Secretary.*

ARGUMENT TO ACCOMPANY LETTER-BALLOT ON ADOPTION OF 112-LB. RE RAIL SECTION

Following the action taken at the March, 1933, Convention of the Association, in approving the 131-lb. RE Rail Section, the Committee on Rail has had under consideration a revision of the 110-lb. RE Rail Section. At a meeting held on June 15, 1933, the Committee agreed upon a rail section weighing 112.4 lb. per yard, to be substituted for the 110-lb. RE Rail Section now in the Manual.

It is desired to promptly submit this new 112-lb. section, with the 131-lb. section already adopted by the Association, to the American Railway Association for endorsement and approval and presentation to the member railroads, so that the new sections may be available for rolling the latter part of this year.

To this end the recommendations of the Committee on Rail are submitted herewith to the Association for adoption by letter-ballot.

In designing this new section, no change was made in the width and thickness of base, as compared with the 110-lb. section, so as not to affect the interchangeability of tie-plates, rail anchors, and the preboring of ties. No change was made in the width of head at the gage line at 5/8-inch below the top of the head.

Reference is made to Fig. 1, on a following page, showing this section. A comparison of its properties with the present 110-lb. RE section follows:

	110-lb. RE	*112-lb. RE*
Stiffness (M. I.)	100.0%	115.5%
Strength (Sec. Mod.)	100.0%	108.1%
Weight or Area	100.0%	101.8%
Area of Head (Total Area 100%)	37.4%	35.9%
Area of Web (Total Area 100%)	23.0%	25.1%
Area of Base (Total Area 100%)	39.6%	39.0%
Ratio M. I. to Area	5.27	5.97
Ratio Sec. Mod. to Area	1.55	1.64
Ratio Base to Height	.88	.83

These desirable increases of the 112-lb. section are secured with comparatively small increase in weight over the present 110-lb. section. It is intended that this new section will be the only section between the 100-lb. RE and the 131-lb. RE sections, and therefore its weight might properly approach the half-way point. Consideration, however, was given to the desire of the users of the present 110-lb. RE section not to increase the weight to any great extent. Within reason, the weight was permitted to fall where it would, as the result of the rail dimensions agreed upon.

The distribution of the metal of the head, web and base for this section falls between that of the present 110-lb. RE section and that of the 131-lb. RE section, both of which have been successfully rolled by the manufacturers.

The betterment of the joint bars is one of the most important considerations and ranks with the improvement of the rail section itself. Any increase in the fishing depth of the rail increases the stiffness and strength of the joint bars. There is not much opportunity to secure these increases by widening the joint bars.

A comparison of a joint bar for the 112-lb. section with a similar type for the present 110-lb. RE section follows:

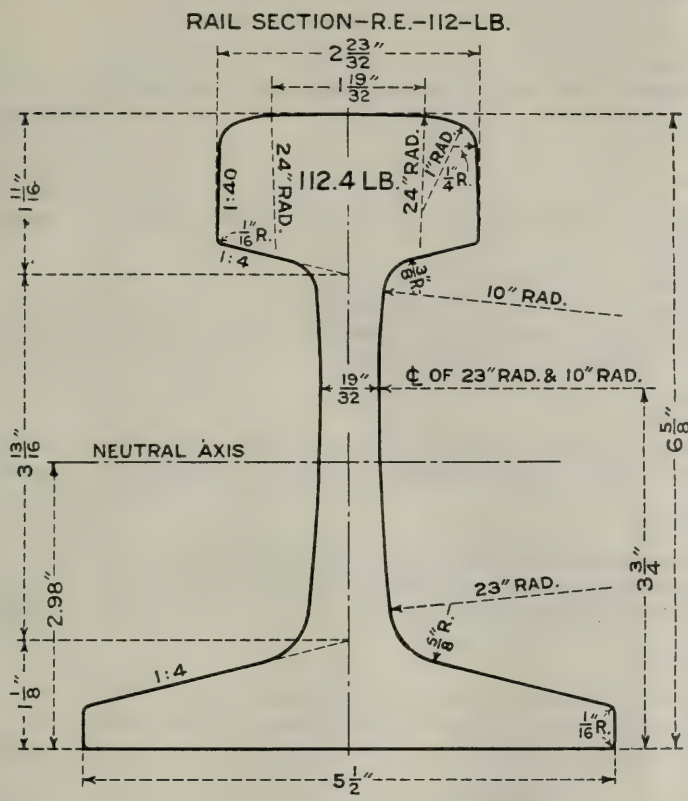
	110-lb. RE	*112-lb. RE*
Stiffness (M. I.)	100.0%	135.0%
Strength (Sec. Mod.)	100.0%	122.6%
Weight	100.0%	108.7%
Ratio M. I. to Area	1.76	2.19
Ratio Sec. Mod. to Area	.81	.91

This indicates a worth-while betterment of the joint bar itself.

In addition to the recommended new rail section, there are several details incident thereto included in the ballot, such as the withdrawal from the Manual of the present 110-lb. RE Rail Section, revisions of the Table of Rail Drillings to Standard Rail Sections, and the revisions of paragraphs 3 and 4 on page 162 of the 1929 Manual, specifying the diameters of the bolts and the bolt holes in the rail. These two paragraphs are revised to conform to the new sections and also to increase the diameters of the bolt holes $\frac{1}{16}$-inch. The present adopted diameters of bolt holes in the rail are only $\frac{1}{16}$-inch larger than the diameters of the bolts, which is insufficient to provide proper clearance for expansion or the admission of the bolts without probable damage to the threads. The proposed revisions conform closely to current practices on the majority of the roads.

The trend of the times is towards standardization and simplified practice, for which there is a strong demand in the interests of economy. It is the purpose of the Association to recommend standards that roads will use; the object being to eliminate the multiplicity of standards, for which railroads have been criticised.

In the revisions of the rail sections, the Committee on Rail has sought to present designs giving maximum utility for the weight of metal. The 131-lb. section has already been adopted. The Committee recommends the proposed 112-lb. section for your favorable consideration.



AREA · HEAD	3.96 SQ. IN.	35.9 %
WEB	2.77 " "	25.1 %
BASE	4.29 " "	39.0 %
TOTAL	11.02 " "	100.0 %

MOMENT OF INERTIA	65.8
SECTION MODULUS, HEAD	18.1
" " BASE	22.1
RATIO M.I. TO AREA	6.0
RATIO SEC. MOD. TO AREA	1.6
RATIO HEIGHT TO BASE	1.20
RATIO BASE TO HEIGHT	0.83

FIG. 1

Recommendations Submitted for Approval

1. Withdrawal from the Manual of the present 110-lb. RE Rail Section, shown on page 143 of the 1929 Manual.
2. Adoption and publication in the Manual, as the standard 112-lb. RE section, of the rail section shown as Fig. 1.
3. Revision of the table headed "Application of Recommended Rail Drilling to Standard Rail Sections," page 162 of the 1929 Manual, by eliminating all reference to 110-lb. RE Rail Section and Drilling.
4. Addition to the table referred to in Recommendation 3, of "112" in first column; "RE" in second column, and "3 3/32-inch" in third column.
5. Revision of paragraph 3, page 162 of the 1929 Manual, to read as follows: "For standard rails up to and including 112-lb. per yard, one-inch bolts and 1⅛-inch bolt holes should be used."
6. Revision of paragraph 4, page 162 of the 1929 Manual, to read as follows: "For standard 131-lb. per yard rail, 1⅛-inch bolts and 1¼-inch bolt holes should be used."

Letter-Ballot on 112-lb. RE Rail Section

Proposal No. 1

Withdrawal from the 1929 Manual, page 143, of the present 110-lb. RE Section.	For	501
	Against	11

Proposal No. 2

Approval of the 112-lb. RE Rail Section, as shown in Fig. 1.	For	502
	Against	10

Proposal No. 3

Elimination of reference to 110-lb. RE Rail Section in table on page 162, 1929 Manual, headed "Application of Recommended Rail Drilling to Standard Rail Sections."	For	501
	Against	11

Proposal No. 4

Insertion in table on page 162, 1929 Manual, of "112" in first column; "RE" in second column, "$3\frac{1}{32}$-inch" in third column.	For	496
	Against	16

Proposal No. 5

Revision of paragraph 3, page 162, 1929 Manual, to read: "For standard rails up to and including 112-lb. per yard, one-inch bolts and 1⅛-inch bolt holes should be used."	For	492
	Against	15

Proposal No. 6

Revision of paragraph 4, page 162, 1929 Manual, to read: "For standard 131-lb. per yard rail, 1⅛-inch bolts and 1¼-inch bolt holes should be used."	For	480
	Against	23

Signed .....

Appendix K

(10) DESIGN JOINT BARS FOR RE RAIL SECTIONS AS DEVELOPED

G. W. Harris, Chairman, Sub-Committee; J. E. Armstrong, W. C. Barnes, A. F. Blaess, N. J. Boughton, C. T. Dike, J. M. Farrin, L. C. Fritch, C. R. Harding, W. H. Kirkbride, H. C. Mann, W. H. Penfield, W. H. Petersen, A. N. Reece, R. T. Scholes, J. R. Watt, Louis Yager.

This subject was added to the Committee assignments during the fiscal year with request for early completion. After intensive study your Sub-Committee designed a joint bar section and assembly for use with the 112-lb. RE rail which the Committee recommends for adoption as standard. As there was need of early action, the Committee's recommendations were submitted to the Association by letter-ballot on January 20, 1934, but the result of this letter-ballot is unknown at the date of this writing.

As a matter of record the form of the letter-ballot of January 20, 1934, referred to is given below.

This report is submitted as information.

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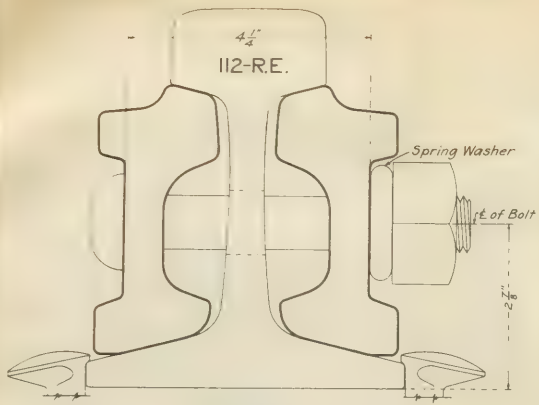
thickness of



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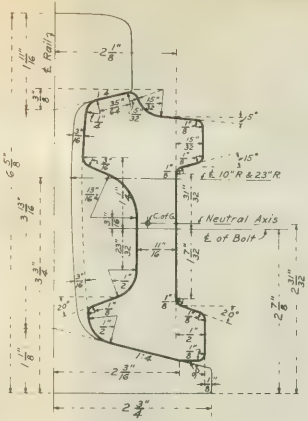
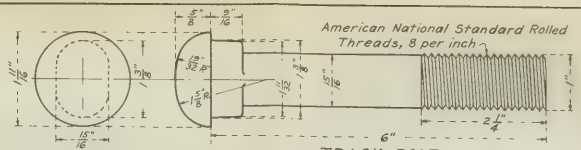
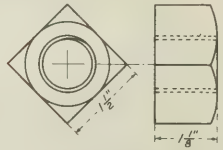


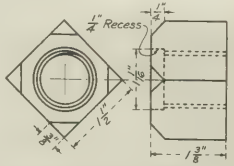
SECTION



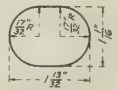
TRACK BOLT



SQUARE NUT
To be used with Spring Washer



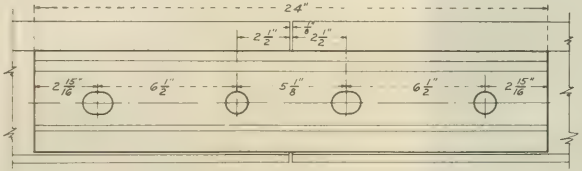
RECESSED NUT
To be used without Spring Washer



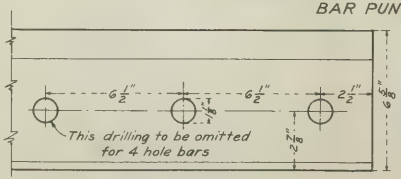
OVAL HOLE

CIRCULAR HOLE

BAR PUNCHING

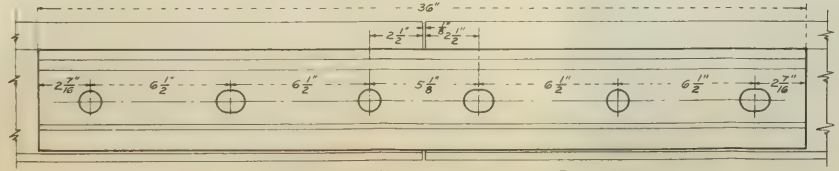


ELEVATION OF 4 HOLE BAR



RAIL DRILLING

PHYSICAL PROPERTIES		ONE BAR	TWO BARS
Moment of Inertia	In⁴	11.8	23.6
Section Modulus	Above N.A. In³	5.2	10.3
	Below N.A. In³	4.9	9.9
Area	Sq. In.	5.67	11.34
Net Weight, 24" Long, Lbs.		37.7	75.4
Net Weight, 36" Long, Lbs.		56.6	113.2



ELEVATION OF 6 HOLE BAR

A. R. E. A.
JOINT BAR AND ASSEMBLY
FOR
112 LB. R.E. RAIL

December 1933

American Railway Engineering Association

LETTER-BALLOT

on

AREA JOINT BAR AND ASSEMBLY FOR 112-LB. RE RAIL

Chicago, January 20, 1934.

To the Members:

At the March 1933 Convention, the Association adopted the 131-lb. RE Rail Section, and since the Convention the 112-lb. RE Rail Section was adopted by letter-ballot dated July 1, 1933.

These sections have been generally adopted for use by those roads that have been using the 130-lb. and 110-lb. RE sections.

The Association has never recommended standard joint bar sections for the several weights of rail. The matter has been left to the determination of each individual road. As a result there is a large number of different types and sections of joint bars, different sizes of bolts and different sizes and spacing of bolt holes in the joint bars and rails.

With the adoption of the new rail sections, it seems appropriate that standard joint bar sections and assemblies be recommended for those sections. At the suggestion of the President of the American Railway Association the subject was assigned to the Rail Committee, to recommend rail joints for the 112-lb. and the 131-lb. RE rail sections.

Plan of the Joint Bar and Assembly for the 112-lb. RE rail is submitted herewith. The plan includes the joint bar section, the bar punching, the rail drilling and the bolt. The Rail Committee recommends this section and assembly to the Association for adoption as standards and for publication in the Manual.

In the event that a majority of the members voting approve the Joint Bar and Assembly for 112-lb. RE rail, it will be presented to the Board of Directors of the American Railway Association for endorsement and approval.

Please indicate your vote on attached coupon and return it to the Secretary's office not later than February 15, 1934.

E. H. Fritch, *Secretary.*

Recommendations Submitted for Approval

1. Adoption and publication in the Manual of the 112-lb. Joint Bar section.
2. Revision of the Revision of paragraph 3, page 162, 1929 Manual, made in Proposal No. 5 Letter-Ballot on 112-lb. RE rail section, July 1, 1933, to read: "For standard rails up to and including 131-lb. per yard, one-inch thread diameter bolts and 1⅛-inch bolt holes should be used."
3. Elimination of Revision of paragraph 4, page 162, 1929 Manual, made in Proposal No. 6 Letter-Ballot on 112-lb. RE rail section, July 1, 1933, which reads: "For standard 131-lb. per yard rail, 1⅛-inch bolts and 1¼-inch bolt holes should be used."
4. Revision of Proposal No. 4 Letter-Ballot on 112-lb. RE rail section, to read: "112" in first column; "R.E." in second column; "2⅞-inch" in third column.
5. Adoption and publication in the Manual of the 24-inch and the 36-inch joint bar bolt hole punching.
6. Adoption of the rail drilling for the 112-lb. RE rail section.
7. Revision of the Standard Track Bolts and Nuts, as given in Supplement to Manual of 1929, Bulletin 327, page 13, Column—"Length Under Head," to read: "From 3 to 7 inches by steps of ¼-inch," and "From 7 to 10 inches by steps of ½-inch." Bulletin 327—page 17, to be revised to cover a recess of ¼-inch and thickness of recessed nut of 1⅜-inch for one-inch diameter bolt.

Recommendations Submitted for Approval

Proposal No. 1

Adoption and publication in the Manual of the 112-lb. Joint Bar section. For Against

Proposal No. 2

Revision of the Revision of paragraph 3, page 162, 1929 Manual, made in Proposal No. 5, Letter-Ballot on 112-lb. RE rail section, July 1, 1933, to read: "For standard rails up to and including 131-lb. per yard, one-inch thread diameter bolts and 1⅛-inch bolt holes should be used." For Against

Proposal No. 3

Elimination of Revision of paragraph 4, page 162, 1929 Manual, made in Proposal No. 6, Letter-Ballot on 112-lb. RE rail section, July 1, 1933, which reads: "For standard 131-lb. per yard rail, 1⅛-inch bolts and 1¼-inch bolt holes should be used." For Against

Proposal No. 4

Revision of Proposal No. 4 Letter-Ballot on 112-lb. RE rail section to read: "112" in first column; "RE" in second column; "2⅞-inch" in third column. For Against

Proposal No. 5

Adoption and publication in the Manual of the 24-inch and the 36-inch joint bar bolt hole punching. For Against

Proposal No. 6

Adoption of the rail drilling for the 112-lb. RE rail section. For Against

Proposal No. 7

Revision of the Standard Track Bolts and Nuts as given in Supplement to Manual of 1929, Bulletin 327, page 13, Column—"Length Under Head," to read: "From 3 to 7 inches by steps of ¼-inch," and "From 7 to 10 inches by steps of ½-inch." Bulletin 327—page 17, to be revised to cover a recess of ¼-inch and thickness of recessed nut of 1⅜-inch for one-inch diameter bolt. For Against

Signed .....

SUPPLEMENT TO REPORT OF COMMITEE IV—RAIL

(Bulletin No. 363, Page 829, Vol. 35—January, 1934)

To the American Railway Engineering Association:

Your Committee presents herewith its report on the design of joint bar and assembly for the 131-lb. RE rail.

At the March, 1933, Convention, the Association adopted the 131-lb. RE Rail Section, and since that Convention the 112-lb. RE Section has been adopted by letter-ballot, dated July 1, 1933.

These sections have been generally adopted for use by those railroads that have been using the 130-lb. and the 110-lb. RE sections.

The Association has never adopted standard joint bar sections for the several weights of rail. The matter has been left to the determination of each individual road. As a result there is a large number of different types and sections of joint bars, different sizes of bolts and different sizes and spacing of bolt holes in the joint bars and rails.

With the adoption of the new rail sections, it seems appropriate that standard joint bar sections and assemblies be adopted for these rail sections. At the suggestion of the President of the American Railway Association, the subject of recommending joint bars for the 112-lb. and the 131-lb. RE rail sections was assigned to this Committee.

The Joint Bar and Assembly for the 112-lb. rail was completed and approved by the Committee on January 4, 1934. As early action by the Association was urgent, on account of the desire of several roads to use the bar, if adopted, with rails for which orders were pending, a letter-ballot was sent out to the members of the Association on January 20, 1934. The result of this ballot was for the adoption of the joint bar and assembly by a vote of 444 to 160.

A plan for a Joint Bar and Assembly for the 131-lb. RE rail is submitted herewith. This joint bar section was designed by Dr. A. N. Talbot, Chairman of the Committee on Stresses in Railroad Track, collaborating with the Sub-Committee having in charge the design of the 131-lb. joint bar.

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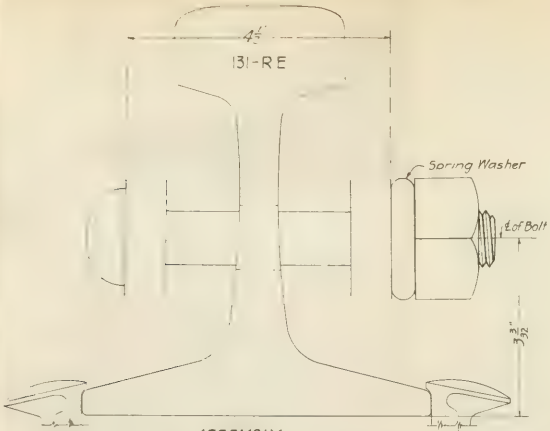

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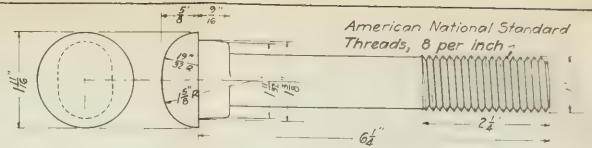
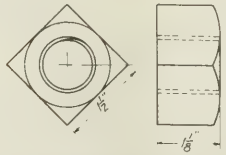
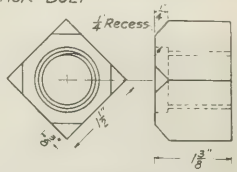


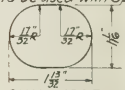
TRACK BOLT



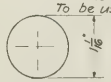
SQUARE NUT
To be used with Spring Washer



RECESSED NUT
To be used without Spring Washer

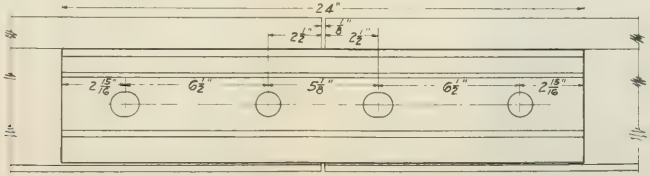


OVAL HOLE

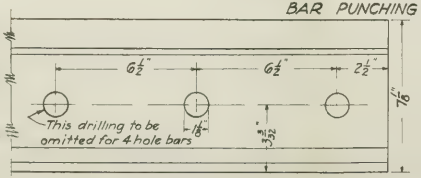


CIRCULAR HOLE

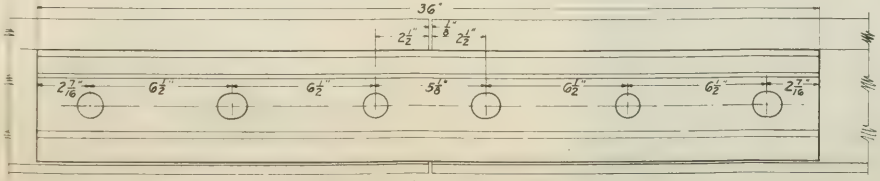
BAR PUNCHING



ELEVATION OF 4 HOLE BAR



RAIL DRILLING



ELEVATION OF 6 HOLE BAR

A. R. E. A.
ASSEMBLY
FOR
131 LB. R. E. RAIL

February 19, 1934

This Sub-Committee was composed of the following members: E. Stimson, Chairman; W. J. Backes, C. B. Bronson, R. Faries, C. W. Johns, Wm. Michel, John V. Neubert, E. E. Oviatt, G. A. Phillips, G. J. Ray, W. P. Wiltsee, J. B. Young.

Recommendations for Adoption and Publication in the Manual:

1. Adopt the 131-lb. RE Joint Bar Section.
2. Change "Height of bolt hole above base of rail" for the 131-lb. RE rail section, adopted by the Association in 1933 from 3¼ inches to 3 3/32 inches.
3. Adopt the 24-inch and the 36-inch joint bar bolt hole punching.
4. Adopt the rail drilling for the 131-lb. RE rail section.
5. Adopt as a whole the plan of the "Joint Bar and Assembly for the 131-lb. RE Rail," submitted herewith.

Respectfully submitted,

The Committee on Rail,

Earl Stimson, *Chairman.*

Chicago, March 5, 1934.

REPORT OF COMMITTEE XXI—ECONOMICS OF RAILWAY OPERATION

J. E. Teal, *Chairman;*
B. T. Anderson,
R. C. Bardwell,
G. S. Crites,
H. C. Crowell,
Olive W. Dennis,
W. N. DeRamus,
J. H. Dyer,
S. W. Fairweather,
J. M. Farrin,
A. Z. Green,
G. W. Hand,
E. M. Hastings,
W. W. Houston,
C. H. R. Howe,
G. D. Hughey,
E. E. Kimball,
Shu-T'ien Li,
M. F. Mannion,
F. H. McGuigan, Jr.,
P. J. Neff,
J. A. Parant,
E. S. Pennebaker,
L. S. Rose,
J. E. Saunders,
Mott Sawyer,
J. F. Pringle, *Vice-Chairman;*
R. T. Scholes,
H. F. Schryver,
B. J. Schwendt,
W. C. Sloan,
C. E. Smith,
H. W. Snyder,
C. H. Stein,
M. F. Steinberger,
R. E. Van Atta,
C. C. Williams,
John Worley,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully presents report covering the following subjects:

1. Revision of Manual, including revision of the method for the determination of proper allowances for maintenance-of-way expenses due to increased use and increased investment.

Report under this assignment is presented as Appendix A, and it is recommended that the last paragraph be adopted for publication in the Manual.

3. Methods or formulae for the solution of special problems relating to more economical and efficient railway operation.

Report under this assignment is presented as Appendix B, and it is recommended that it be received as information.

5. Methods for determining most economical train length, considering all factors entering into transportation costs, collaborating with Operating Division.

Report under this assignment is presented as Appendix C, and it is recommended that it be received as information.

6. Effect of volume of traffic on railway operating expenses, collaborating with Committee XXII—Economics of Railway Labor.

Report under this assignment is presented as Appendix D, and it is recommended that it be received as information.

Progress is reported on the following subjects:

2. Methods for obtaining a more intensive use of existing railway facilities, with particular reference to securing increased carrying capacity:

(a) Without material additional capital expenditures.
(b) With due regard to reasonable increases in capital expenditures consistent with traffic requirements.

4. Most economical makeup of track to carry various traffic densities, collaborating with Committees I—Roadway, II—Ballast, III—Ties, IV—Rail, V—Track, and X—Signals and Interlocking.

7. Discontinuance of non-paying trains and agencies, rendered so by all forms of highway competition.

8. Operation with reduced number of main tracks.

Respectfully submitted,

The Committee on Economics of Railway Operation,
J. E. Teal, *Chairman.*

Bulletin 364, February, 1934.

Appendix A

(1) REVISION OF MANUAL, INCLUDING REVISION OF THE METHOD FOR THE DETERMINATION OF PROPER ALLOWANCES FOR MAINTENANCE-OF-WAY EXPENSES DUE TO INCREASED USE AND INCREASED INVESTMENT

J. F. Pringle, Chairman, Sub-Committee; H. C. Crowell, S. W. Fairweather, J. M. Farrin, C. H. R. Howe, E. E. Kimball, M. F. Mannion, F. H. McGuigan, Jr., L. S. Rose, C. E. Smith, C. H. Stein, J. E. Teal.

The subject-matter pertaining to maintenance of way expenses now appearing in the Manual was adopted for publication at the Annual Convention in 1925. Since that time there have been changes in maintenance of way practices which have led to the suggestion that the figures shown on page 1430 of the Manual of 1929, under Column 4, "Per cent affected by use," should be revised to conform to current practices.

The figures appearing in the Manual are not intended to be final, but, as stated in the Manual on page 1430, "These percentages may be varied to suit the circumstances of each particular problem."

After carefully reviewing the figures, your Committee are of the opinion that there has not been sufficient change in maintenance of way practices or sufficient further information developed to warrant any changes, especially in view of the wording of the text above quoted.

Your Committee have found, however, that the method has been used under conditions and for purposes contrary to the original intention, which has led to erroneous deductions, and therefore recommend that the following cautionary paragraph be included in the Manual on page 1432, after the first paragraph at top of page:

> "Care should be exercised in selecting the period to be used as the base period for comparisons. The total equivalent gross ton miles in the base period should be the normal equivalent gross ton miles, that is, the normal use for which the property is maintained. The base period should extend over a sufficient period, with normal conditions, in order that the maintenance expenditures during the period will be normal. Comparisons of one year with another cannot be made under this method, unless the equivalent gross ton miles and maintenance expenditures for the year used as the base period are the normal equivalent gross ton miles and normal expenditures for the property."

Appendix B

(3) METHODS OR FORMULAE FOR THE SOLUTION OF SPECIAL PROBLEMS RELATING TO MORE ECONOMICAL AND EFFICIENT RAILWAY OPERATION

C. H. R. Howe, Chairman, Sub-Committee; W. N. DeRamus, F. H. McGuigan, Jr., J. A. Parant, E. S. Pennebaker, J. E. Saunders, H. W. Snyder

ECONOMIC EFFECT OF THE 131-LB. R.E. SECTION RAIL ON THE COST OF OPERATION AS COMPARED WITH THE 130-LB. R.E. SECTION

The adoption of a new standard 131-R.E. rail section by the American Railway Engineering Association at its March, 1933, convention, raises the question as to what economies in the cost of operation, if any, would be gained by replacing the 130-lb. R.E. rail with the 131-lb. R.E. section.

The objective sought in the change of sections is greater girder strength and improved texture without undue sacrifice of lateral strength or other attributes of value

in the 130-lb. R.E. section. If this is accomplished, the result should be longer life of the rail.

The purpose of this analysis is to determine whether or not an improvement has been secured. The economic comparison which follows has been greatly simplified by following, in a large measure, the methods employed by A. N. Reece, Chief Engineer of the Kansas City Southern Railway, which were published as a monograph in Vol. 31, A.R.E.A. Proceedings; the research work by James M. Farrin, Special Engineer of the Illinois Central Railroad in Track Combination Evaluation; the studies on the subject of Ties, by Dr. Hermann von Schrenk; and the data obtained from the experiments conducted by Prof. E. E. Schmidt, of the University of Illinois.

All the data used in connection with tonnage and costs of operation, maintenance of way and equipment are taken from the permanent records of a Class I railway, which will be designated in this report the North and South Railway.

COMPARISON OF THE NEW 131-LB. R.E. AND THE OLD 130-LB. R.E. RAIL SECTIONS

The outstanding difference between the two sections is the increase in the moment of inertia of the 131-lb. R.E. rail, the 130-lb. R.E. having a moment of 77.4, the 131-lb. R.E. a moment of 89.0, this being an increase of 15.0 per cent. This increased moment is the result of decreasing the base area 0.20 sq. in., or 4.00 per cent, and adding the metal taken from the base and head plus an additional amount of 1.56 lb. per yard to the web to increase the height of the section by $\frac{3}{8}$-in. The area of the head remains approximately the same, the actual decrease being but 0.10 sq. in. but the design of the head is changed materially, the depth being decreased $\frac{3}{32}$-in. and the width increased $\frac{1}{16}$-in. The effect of this change in head design on cooling, texture and hardness will be discussed later under the topic Life of Rail.

Whereas the total lateral moment of inertia of the section has been slightly reduced, the lateral moment of inertia of the head has actually been increased from 2.8 to 3.0. This will effect not only a better distribution of stresses in the web but also reduce stresses in the head, as a part of these stresses are due to the lateral forces on the rail.

Comparison of the section moduli of the heads and bases of the two sections shows that the 131-lb. R.E. is better balanced than the 130-lb. R.E. This should produce more nearly equal stresses about the neutral axis of the rail in its action as a continuous girder, and should tend to reduce the effect of the stress in aggravating transverse fissure development and other defects in the rail head. The vertical sides of the head should improve the design and fit of switch points.

The principal change in the base is a reduction of $\frac{1}{32}$-in. in the thickness.

The change in the web design whereby the point of minimum thickness is raised from $3\frac{3}{8}$-in. to $4\frac{1}{4}$-in. above bottom of rail, is of material benefit, for notwithstanding the increased radius of the curve as it swings down there is more metal in the web, just above the base, than there is in the 130-lb. R.E. at this point. This increase in bulk should have the effect of slightly retarding the cooling of the base in rolling, thus modifying the after-rolling camber.

Life of Rail

The controlling factor in the economics of the rail itself is the cost of service life obtained measured in gross tons traffic, specifically designated "Gross Ton Miles per Mile". There are many elements that affect the service life, and an attempt is made in this report to review those that are considered important.

Effect of Wear on Life of Rail

At the present time wear due to the abrasion of the rail head is not a major cause of removal from main line track of the North and South Railway, either on tangent or curves. On the latter the extensive use of curve grease has largely disposed of this factor, and curve rails now remain in track until necessary to remove on account of batter, underhead wear, wheel burns and surface or line bending. Measurements of rail removed from main line track on the North and South Railway show the average depth of head wear to be $\frac{5}{32}$-in., which in itself is not sufficient cause for removal.

Much work is being done at the present time in an effort to decrease the number of rail removals on account of batter, such as heat treating, rebuilding by welding, bevelling rail ends and the use of improved rail joints. By these means the life of rail may be so extended that uniform wear may be an important consideration in determining its service life.

The depth of head of the 131-lb. R.E. is $\frac{3}{32}$-in. less than the old 130-lb. R.E. but it has approximately the same head area and is $\frac{1}{16}$-in. wider, which with its improved contour of wearing surface that more closely approximates that of wheel flanges and treads than the 130-lb. R.E., should produce more uniform cold rolling and reduce the rate of sideflow and wear.

Effect of Carbon Content Upon the Life of Rail

Carbon content plays an important part in the life of rail, but it is assumed in the case of the two sections considered that the carbon content range is the same and this factor is disregarded.

Effect of Amount of Rolling and Rapidity of Cooling Upon the Life of Rail

The two sections being of approximately the same weight it is evident that the amount of rolling or working will be the same, so that if we are to find an improvement in this respect it must be as a result of cooling. Application of the head area-perimeter ratio test as shown in Mr. Reece's Table IV indicates that the new section will be slightly harder and the rate of batter slower than the 130-lb. R.E., as shown by the following tabulation:

Rail Section	*Area of Head (Sq. In.)*	*Perimeter (In.)*	*Area–Perimeter Ratio*	*Relative Hardness*	*Relative Rate of Batter*
85 K.C.S.	3.14	6.86	.458	100 per cent	100 per cent
130 R.E.	4.63	8.39	.552	83	121
131 R.E.	4.53	8.37	.540	85	118

Effect of Stiffness of Rail Upon its Life

Joint bars are not as stiff as the rails they connect, therefore there is a break in the depression curve of the rail at the joint as the bars are effective only to the extent of producing a reduction of 80 per cent in the slope between the surface of the abutting rail ends. Based on this theoretical consideration it may be assumed that a reduction in rail batter is obtained equal to the reduction in slope between the rail surfaces. When Mr. Reece's Table V is examined, it will be noted that there is but 3 per cent difference between the Relative Slope and Rail Batter percentages of the 127-lb. rail section having a moment of inertia of 83.7 and the 150-lb. section with a moment of 121.1. From this it will be seen that the reduction in the batter of the 131-lb. R.E., section having a moment of 89.0, compared with a moment of 77.44 for the 130-lb. R.E. is about 1 per cent.

Effect of Width of Head Upon the Life of Rail

It is reasonable to assume that the rate of batter will vary inversely in proportion to the width of surface exposed to batter. The 131-lb. R.E. head is 3-in. wide and the 130-lb. R.E. $2\frac{15}{16}$, an increase in width, or a batter decrease, of 2 per cent.

Estimated Life of the Two Rail Sections

Summing up the effects of the factors that have been discussed, it is found, that with a life of 7.5 years with a gross ton miles traffic of 18.7 millions per year for the 130-lb. R.E., there will be an increase of 0.38 years for the 131-lb. R.E. section, as indicated below:

	Relative Batter in Per Cent Due to:							
Rail Section	*Increased Width of Head*	*Carbon Content*	*Slower Cooling and Less Rolling*	*Increase in Rail Stiffness*	*Combined Effects*	*Relative Life Per Cent*	*Life in Million Gross Tons*	*Life in Years*
130 R.E.	100	100	100	100	100	100	140.2	7.50
131 R.E.	98	100	98	99	95	105	147.2	7.88

Material Cost of the Two Rail Sections

There being so little difference in the life of the two rail sections, or in the type or size of fittings (excepting the joint bars which have not as yet been designed) and as the cost of laying will be the same in both cases, the cost of rail in place will be considered that of the actual tonnage less salvage value, plus the annual interest of the first cost of each section.

Rail Section	*Cost Per Ton*	*Salvage*	*Cost Per Mile*	*Interest @ 5 per cent*	*Labor Renewing*	*Total Cost Per Mile*	*Million G.T.M.*	*Cost Per Million G.T.M.*
130 R.E.	$40	$21	$3,871	$1,452	$750	$6,073	140,185	$43.32
131 R.E.	40	21	3,917	1,543	750	6,210	147,194	42.19

Effect of Rail Upon Track Maintenance

In a study of this subject prepared by James M. Farrin, Special Engineer of the Illinois Central Railroad, and published in Vol. 28, A.R.E.A. Proceedings, there is presented a method by which various track makeups may be evaluated in terms of track labor hours. Numerous combinations of rail, ties, ballast and subgrade are shown by Mr. Farrin, but as in our present comparison all factors remain unchanged except rail section, we are concerned only with the effect that the change in rail stiffness will have upon the stiffness of the entire track structure, and consequently with the cost of maintenance.

The costs of maintenance shown by Mr. Farrin are the composite averages of a number of railways, but the determination of costs on any railway should be based on actual record of its own expenditures, and not on general payroll percentages. The North and South Railway records permit the use of actual cost figures in sufficient detail to enable us to make a reasonable estimate of the effect that the new 131-lb. R.E. section will have on the cost of maintenance.

During the year 1930 the labor cost on the 130-lb. rail territory was $579, or 1399 man hours per mile of track, including all labor costs in connection with line and surfacing, ballasting, respacing, regaging and tightening bolts.

As the difference in maintenance costs is not great for the two sections that we are comparing, we may accept Mr. Farrin's values for comparative maintenance labor percentages for various rail sections as being reasonably correct. Plotting the percentages,

and moments of inertia for the respective sections, we obtain a curve from which we may determine the values of the 130-lb. R.E. and 131-lb. R.E. sections (see chart appended). These percentages may be interpolated in the percentages shown in Mr. Reece's Table X, at the same time substituting actual costs of the North and South Railway. Doing so we find a reduction in maintenance labor cost of $3.00 per million gross ton miles per mile, as indicated by the table below:

Rail Section	*Track Rating Per Cent*	*Labor per Mile per Year Man Hours*	*Comparative Maintenance Labor Per Cent*	*Cost of Labor per Mile per Million G.T.M.*	*Saving per Mile per Million G.T.M.*
85 K.C.S. Ry. ...	34 per cent	3375	100 per cent	$75	$ 0
100 R.E.	50	2150	62	48	27
115 Dudley	62	1600	47	35	40
127 "	69 *	1300	39 *	29	46
130 R.E.	67	1399	41	31	44
131 R.E.	71	1250	37	28	47
150 R.E.	80	1075	30	24	51

* Correction has been made from Mr. Farrin's charts.

Effect of Rail on Maintenance or Equipment

Wear and tear on equipment is affected by the condition of track, and the stiffness of the rail is an important factor in reducing the cost of locomotive and car repairs. In accordance with the A.R.E.A. Proceedings, Vol. 24, page 1060, 76.45 per cent of the costs chargeable to the above repairs will be affected by use of equipment. Quoting Mr. Reece: "The effect of use, or traffic, is damage from track condition, damage from train movement, and wear resulting from the production of energy." It is assumed that each of these causes equally affect the maintenance of equipment; then 25.48 per cent of the cost of the above repairs will be affected by track conditions. In 1930 the cost of such repairs was $3,040 per mile, or $93 per million gross ton miles, for the amount of the above accounts affected by track condition. The weighted average of the rail in North and South Railway main tracks in 1930 was 107.5-lb. per yard. On the above basis and having a cost of $93 per million gross ton miles, the respective values for the 130-lb. R.E. and 131-lb. R.E. sections have been determined by plotting the values for track stiffness given in Mr. Reece's Table XII and interpolating the values for the 130-lb. R.E. and the 131-lb. R.E. based on moments of inertia.

From the tabulation below it is noted that the net saving of the 131-lb. R.E. over the 130-lb. R.E. is $3 per Million Gross Ton Miles.

Rail Section	*Comparative Damage to Equipment from Track*	*1930 Cost of Repairs Due to Track per Million G.T.M. of Traffic*	*Savings per Mile per Million G.T.M.*
85 K.C.S. Ry.	100 per cent	$109	$—
100 R.E.	90	98	11
N&S Avg.	85.5	93	16
115 Dudley	81	88	21
127 "	75	82	27
130 R.E.	76.5	83	26
131 R.E.	73.5	80	29
150 R.E.	68	74	35

Economies in Cost of Tie Renewals Per Mile of Main Track

Examination of the figures in Mr. Reece's Table XI shows that the savings effected by slight changes in rail sections are small. Even between the 127-lb. and the 150-lb.

sections the difference is but $3 per Million Gross Ton Miles. The causes for tie removal due to mechanical wear as set forth in Dr. von Schrenk's monograph in A.R.E.A. Bulletin 306, and which Mr. Reece states in his paper amounted to 57 per cent on his railway for the year 1927, are accepted without serious question. Even neglecting the conditions of the general stiffness of track and accepting the moment of inertia ratio as a criterion, no serious discrepancy will occur in a comparison of the 130-lb. and 131-lb. R.E. sections.

During the year 1930 the tie renewals on North and South Railway 130-lb. territory averaged 169.7 per mile. As a number of those removed were untreated ties it is only fair to assume that had they all been treated the number of renewals would not have exceeded 160 per mile. Fifty-seven per cent of the 160 per mile renewed is 91 ties, and as the average cost of renewals in place was $1.60 per tie, the cost per mile was $146, or $8 per Mile per Million Gross Tons Miles. A reduction based on an increase of fifteen per cent in rail stiffness would be approximately one dollar.

Effect of Rail Upon Train Operation

Quoting Mr. Reece's article, "A decrease in train resistance effects a larger reduction in the cost of train operation than does a corresponding decrease in ruling grade, inasmuch as a heavier train can be handled not only on the ruling grade but also on all other grades with the same tractive effort and work as before. With rail offering less train resistance, the tonnage per train can be raised until the tractive effort is the same as previously, and a given amount of tonnage can be handled with fewer trains, less work and less cost." (Or if it is preferable, the original rating may be held but speed increased. Either change in operating method might be used to reduce train hours.)

The values for resistance shown in Mr. Reece's Table XV were calculated from the results of dynamometer car and other tests made on the Kansas City Southern Railway using 4.0 lb. per ton train resistance as basis. This figure being in accord with the experiments of Prof. E. E. Schmidt on "Freight Train Resistance," Bulletin 43, University of Illinois. The values for the 130-lb. R.E. and 131-lb. R.E. sections were found by plotting the reduction in resistance given in Table XV together with the respective moments of inertia, and interpolating the two R.E. sections.

			Per Million Gross Ton Miles of Traffic					
			Train Miles per Mile					
Rail Section	*Reduction to Resistance Lbs. per Ton*	*Total Resistance on a 0.5 Per Cent Grade*	*Required to Handle Tonnage 1930*	*Total Reduction*	*Reduction per Million G.T.M.*	*Total Cost per Train Mile Affected*	*Net Saving per Mile per Million G.T.M.*
85 K.C.S. Ry. ..	0.00	14.00	4760	0	0	$1.12	$ 0
100 R.E.	0.15	13.85	4709	51	2.7	1.12	3.02
115 Dudley	0.26	13.74	4671	89	4.8	1.12	5.38
127 "	0.34	13.66	4644	116	6.2	1.12	6.94
130 R.E.	0.32	13.68	4651	109	5.8	1.12	6.49
131 R.E.	0.36	13.64	4637	123	6.6	1.12	7.38
150 R.E.	0.40	13.60	4624	126	7.3	1.12	8.18

During the year 1930 the gross ton mileage per mile of track on the 130-lb. rail territory of the North and South Railway was 18,691,319, and the freight train mileage per mile was 4651. The average tonnage per train was 4019 gross tons. The track mileage 1629.1. For purpose of comparison the 0.5 ruling grade is taken as a basis. With train resistance lowered, the tonnage rating can be raised, and the number of trains required to handle the same tonnage can be reduced.

As an adjustment of 12 tons would be impractical in the case of an individual train, the benefit, if any, of an increased tonnage rating must be derived from cumulative

results. It has been stated above that for the 130-lb. R.E. rail, 4651 trains averaging 4019 tons each were required to handle the 18,691,319 gross tons traffic. It being the practice, on the railway in question, to rate trains in terms of fifty-ton units, the average of 4019 tons is apparently the cumulative result of occasionally exceeding an established rating of 4000 tons. Expressing this in even unit tonnage we find that the 4019 average tonnage would ensue from handling:

2905 trains at 4000 tons each
1746 " " 4050 " "
———
4651 trains

The estimated increase in rating can be applied in the following manner. Adding the 12 tons to the 4019 tons average, and establishing a new rating of 4050 tons, the new average rating should be 4031 tons. This would result from handling:

2905 trains at 4050 tons each
1732 " " 4000 " "
———
4637 trains

From the table above it will be noted that on a 0.5 per cent ruling grade, 130-lb. R.E. rail, the resistance is 13.68-lb. per ton, and 4651 trains, rating at 4019 gross tons each, are required to handle the 18,691,319 gross tons per mile. The resistance of the 131-lb. R.E. rail is 13.64 lb. per ton, and with tractive effort remaining the same, the number of trains per mile and the gross tons per train are proportional to the resistance of the two rail sections.

The values for the 131-lb. R.E. section are:

$$\frac{\text{18,691,319 G.T.M. per Mile} \times \text{13.64 lb. per Ton Resistance}}{\text{4,019 G.T. per Train} \times \text{13.68 lb. per Ton Resistance}} = \text{4637 Train Miles per Mile}$$

and $$\frac{\text{18,691,319 Gross Ton Miles per Mile}}{\text{4,637 Train Miles per Mile}} = \text{4031 New Tonnage Rating}$$

which is an increase of 12 gross tons.

The train miles per mile required for the 130-lb. R.E. rail is 4651 and for the 131-lb. R.E. rail 4637. The difference being 14 train miles per mile, the reduction per million gross ton miles is

$$\frac{\text{14.0 Train Miles per Mile}}{\text{18.7 Million G.T.M. per Mile}} = \text{0.8 Train Miles per Million G.T.M.}$$

Then as the cost per train mile is $1.12 the saving will be $1.12 × 0.80, or $0.90 per million gross ton miles per mile, as shown in the table.

The train mile costs are those given in the report to the Interstate Commerce Commission for 1930, and consist of 49 cents for wages of engine and train crews; 48 cents for lubricants, other supplies, locomotive repairs and engine house expense—of which 86 per cent, or 42 cents, was considered due to traffic; 19 cents for fuel; and 2 cents for water, a total of $1.12 per train mile.

Recapitulation

A summary of the factors entering into the economic value of the different rail sections per track mile follows:

Rail Section	*Saving in Track Labor*	*Saving in Tie Renewals*	*Saving in Maint. of Equipment*	*Saving in Train Operation*	*Total of Savings*	*Cost of Rail in Place*	*Net Savings*
131 R.E.	$47.02	$1.00	$28.80	$7.39	$84.21	$42.19	
130 R.E.	43.72	0.00	25.54	6.50	75.76	43.32	
Saving 131 R.E. over 130 R.E...	$ 3.30	$1.00	$ 3.26	$0.89	$ 8.45	$ 1.13	$9.58

As the net saving per million gross tons per mile is $9.58, the total saving per mile per year would be, based on 1930 tonnage, $9.58 × 18.7 million G.T.M. per mile = $179.15, and as there are 1629.1 miles of 130-lb. rail track the total saving would be $179.15 × 1629.1 = $291,853 per year. This total saving would not be wholly affected until all the 130-lb. R.E. rail now in track has been replaced by the 131-lb. R.E. The saving for 1933 new rail program would be 179 miles × $179.15, or $32,068.00 of which 45 per cent would be for track labor and tie renewals. Future savings would be cumulative in line with such yearly programs as may be completed.

As stated at the outset, the preceding investigation of economics has followed the methods outlined in Mr. Reece's report. It has been given in detail, so as to bring out the essentials, but it should be considered that it is based on several assumptions, where actual data are not available. Other lines of investigation might appear to point to smaller savings, therefore the figures given above should be taken as indication that a general saving will be effected, rather than as a definite statement of the amount of reduced cost.

Conclusions

The 131-lb. R.E. Section is an improvement over the 130-lb. R.E. Section for reasons as follows:

The increased girder strength of the 131-lb. R.E. section should produce better riding track, with less damage to equipment and track and a lower operating cost.

The improvement in the design of the rail head should result in better quality of metal, thus prolonging rail life and decreasing possibility of accidents due to breakage.

These factors should result in an appreciable saving without materially increasing investment.

130-LB. R.E. AND 131-LB. R.E. RAIL SECTION

PHYSICAL DATA SHEET

Properties	*Sections* 130-lb. R.E.	131-lb. R.E.
Area of Head	4.63 Sq. In.	4.53 Sq. In.
Per Cent of Total Area	36.4%	35.2%
Area of Web	3.02 Sq. In.	3.47 Sq. In.
Per Cent of Total Area	23.8%	27.0%
Area of Base	5.06 Sq. In.	4.86 Sq. In.
Per Cent of Total Area	39.8%	37.8%
Total Area of Section	12.71 Sq. In.	12.86 Sq. In.
Moment of Inertia—Vertical	77.40	89.00
" " " —Lateral	14.9	14.5
Section Modulus—Head	20.80	23.00
" " —Base	25.60	27.00
Width of Head	$2\frac{15}{16}$ In.	3 In.
Depth of Head	$1\frac{27}{32}$ In.	$1\frac{3}{4}$ In.
Thickness of Web	$\frac{21}{32}$ In.	$\frac{21}{32}$ In.
Width of Base	6 In.	6 In.
Total Height	$6\frac{3}{4}$ In.	$7\frac{1}{8}$ In.
Weight per Yard	129.64 Lbs.	131.2 Lbs.
Gross Tons per Mile-Track	203.72	206.17
Cost per Ton	$ 40.00	$ 40.00
Cost per Mile-Track	8149.00	8247.00
Cost per Mile Less Salvage $21.00 per ton	3871.00	3917.00

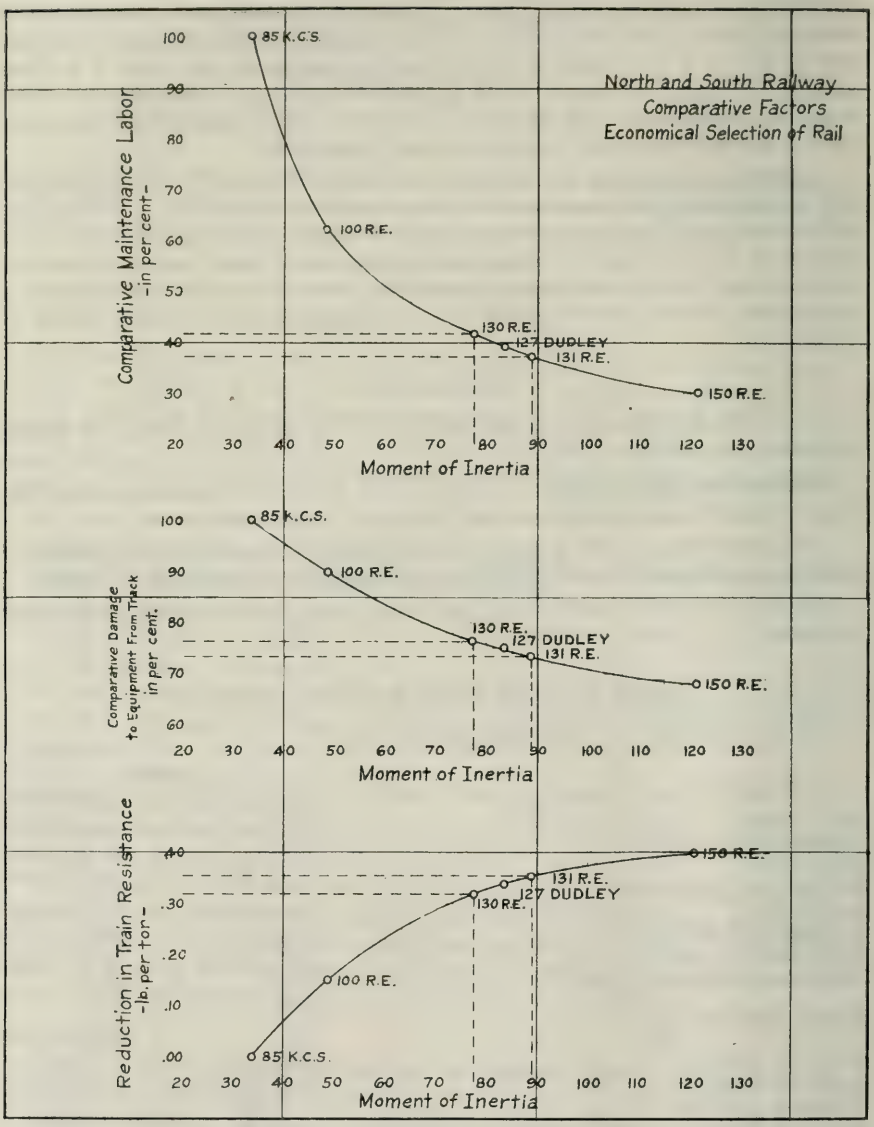
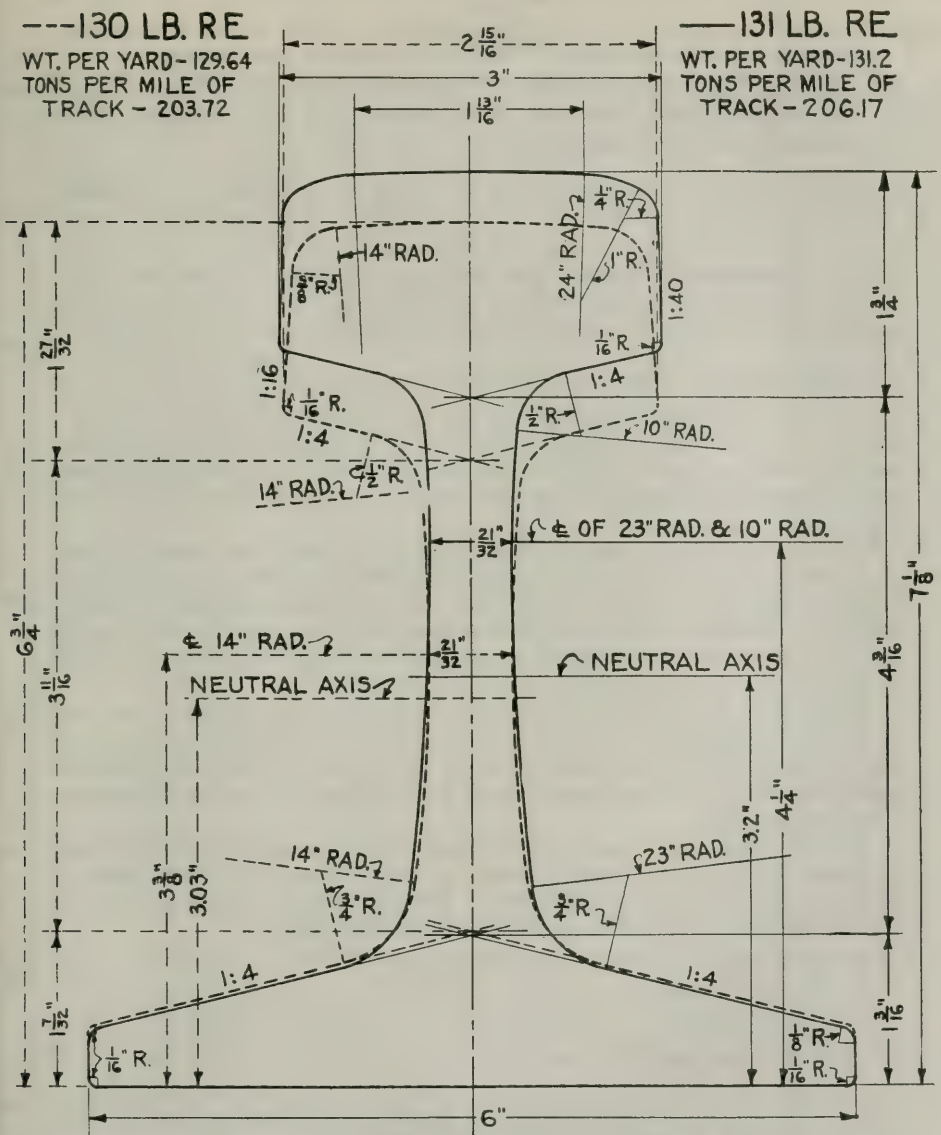

North and South Railway
Comparative Factors
Economical Selection of Rail
Comparative Maintenance Labor
-in per cent-
85 K.C.S.
100 R.E.
130 R.E.
127 DUDLEY
131 R.E.
150 R.E.
Moment of Inertia
Comparative Damage
to Equipment From Track
in per cent.
85 K.C.S.
100 R.E.
130 R.E.
127 DUDLEY
131 R.E.
150 R.E.
Moment of Inertia
Reduction in Train Resistance
-lb. per ton-
150 R.E.
131 R.E.
127 DUDLEY
130 R.E.
100 R.E.
85 K.C.S.
Moment of Inertia

FIG. 1



PROPERTIES:-	130 LB. RE	131 LB. RE
AREA: HEAD	4.63 SQ. IN. - 36.4%	4.53 SQ. IN. - 35.2%
WEB	3.02 " " - 23.8%	3.47 " " - 27.0%
BASE	5.06 " " - 39.8%	4.86 " " - 37.8%
TOTAL	12.71 " " 100.0%	12.86 " " 100.0%
MOMENT OF INERTIA	77.40	89.00
SECTION MODULUS-HEAD	20.80	23.00
BASE	25.60	27.00
RATIO - M.I. TO AREA	6.09	7.00
SEC. MOD. TO AREA	1.64	2.00

FIG. 2

Appendix C

(5) METHODS FOR DETERMINING MOST ECONOMICAL TRAIN LENGTH, CONSIDERING ALL FACTORS ENTERING INTO TRANSPORTATION COSTS

L. S. Rose, Chairman, Sub-Committee; H. C. Crowell, G. D. Hughey, E. E. Kimball, J. A. Parant, H. F. Schryver, W. C. Sloan, H. W. Snyder, John Worley.

The Committee's report this year is in two parts—

(I) A supplement to the 1933 report on the capacity of steam locomotives.

(II) A preliminary comparison of freight train and yard switching performance for the purpose of noting the effect of operating heavy trains upon yard performance.

(I) Supplementary Report on the Capacity of Steam Locomotives

Last year's report in connection with the Committee's assignment consisted of a study of the characteristics and performances of typical steam locomotives for the purpose of developing a simple method for determining the weight of train and the speed which will give the maximum gross ton miles per hour for various classes of locomotives and trains on various grades.

A number of tables covering a limited variety of locomotives were computed and a chart which was intended to be used for making adjustments in the tables was prepared. In applying the study to a number of problems a few errors have been discovered in the tables and some difficulty has been experienced in the use of the chart. For these reasons one of the objects of this supplement is to correct the errors, improve the chart and extend the tables to cover additional classes of locomotives.

Advantage is also taken of this opportunity to present a few examples to show how the data can be applied in the preliminary determination of locomotive capacities and other factors depending upon them. Some of the formulas in last year's report are repeated in order that all of the essential steps can be followed without the inconvenience of referring elsewhere.*

The new master chart shown on the opposite page is arranged to give the weight on drivers in terms of the weight of engine and also in terms of the total weight of engine and tender for typical locomotives in order that adjustments can be made for various weights of tenders when using the tables which follow later.

Example.—Find the adjustment required for the tender of the following locomotive:

Weight on drivers	122 tons
Weight of engine	182 tons
Weight of tender	140 tons
Total weight engine and tender	322 tons

Solution.—The ratio of the weight on drivers to the weight of engine is 122/182 or .67. Look for 67 per cent on the vertical scale, Fig. 1, and note that the weight on drivers for the corresponding typical locomotive amounts to 40.75 per cent of the total weight of engine and tender. Thus the weight of the typical locomotive including tender is 122/.4075 or approximately 300 tons. The weight of the tender for the typical locomotive is therefore 300 minus 182 or 118 tons against 140 tons for the given locomotive. Hence the adjustment for the excess weight of tender amounts to 22 tons, which must be deducted from the weight of trains obtained from the tables corresponding to the typical locomotive, as explained later.

* See also the following articles and discussions: "Transactions of the American Society of Mechanical Engineers," July 30, 1933, Vol. 55, No. 9. "Report of R. A. Black, American Association of Railroad Superintendents," June, 1932. Baldwin Locomotive Company's Publication, 1932.

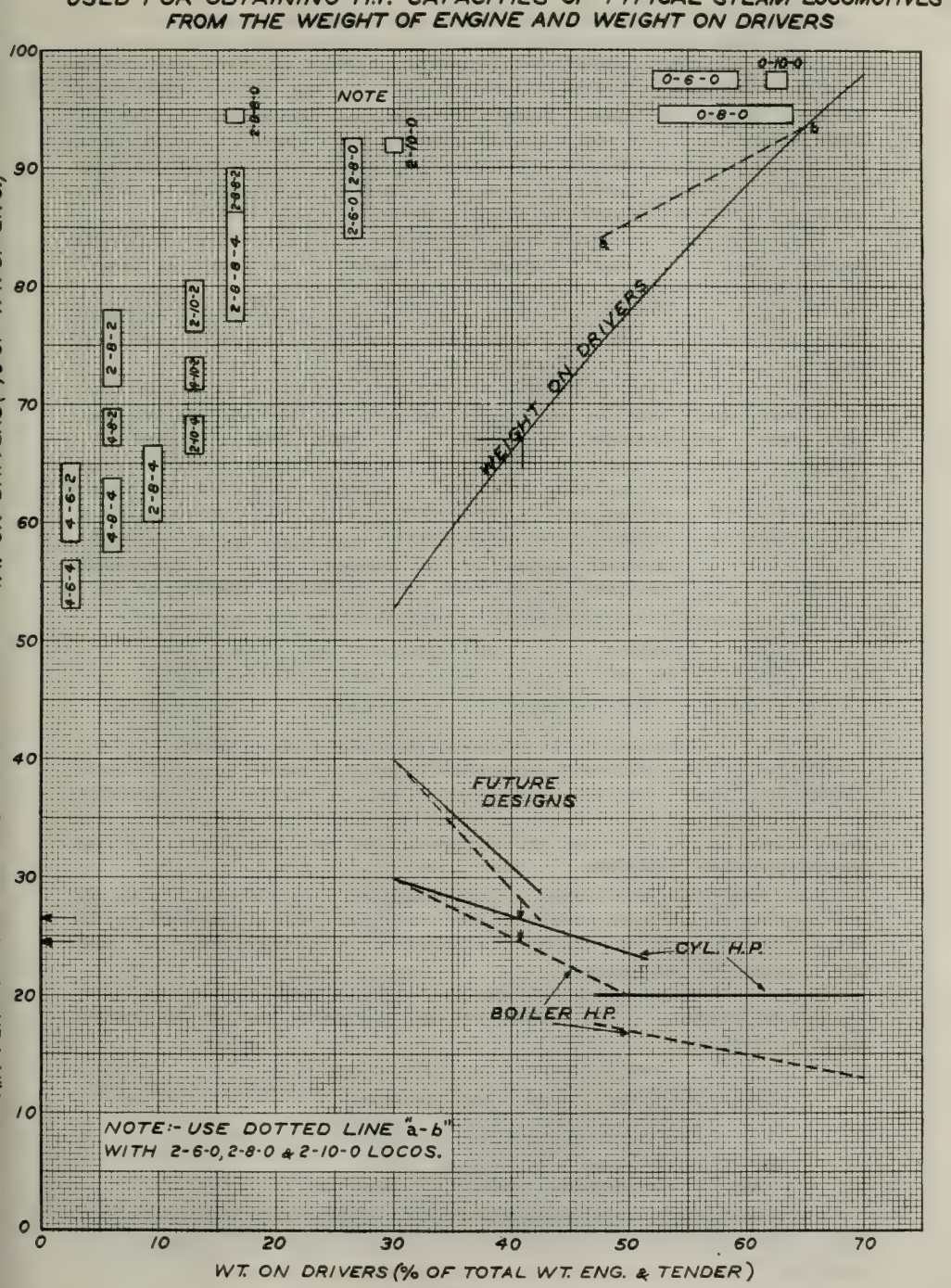


CHART
USED FOR OBTAINING H.P. CAPACITIES OF TYPICAL STEAM LOCOMOTIVES
FROM THE WEIGHT OF ENGINE AND WEIGHT ON DRIVERS
NOTE
0-6-0
0-10-0
0-8-0
2-8-0
2-10-0
2-6-0
2-8-0
2-8-2
2-8-4
2-8-2
2-10-2
4-8-2
2-8-4
4-8-2
4-8-4
2-8-4
4-6-2
4-6-4
WEIGHT ON DRIVERS
FUTURE DESIGNS
CYL. H.P.
BOILER H.P.
NOTE:- USE DOTTED LINE "a-b" WITH 2-6-0, 2-8-0 & 2-10-0 LOCOS.
0
10
20
30
40
50
60
70
80
90
100
WT. ON DRIVERS (% OF TOTAL WT. ENG. & TENDER)

Fig. 1

A new feature of the master chart is the scheme adopted for showing the range covered by various classes of locomotives as indicated by the rectangles in the upper left-hand part of the chart. Thus it will be seen that the weight on drivers for the 4–6–4 type of locomotives as indicated by the rectangle 4–6–4 will range between 52.5 and 57.0 per cent of the weight of engine. Similarly the weight on drivers for the 4–6–2 type will range between 58.5 and 65.0 per cent of the weight of engine and so on for other classes of locomotives. The greater the number of drivers the greater will be the percentage of weight on drivers. The percentage of weight on drivers also increases for a given number of drivers when the number of leading or trailing axles is reduced.

The 2–6–0, 2–8–0 and 2–10–0 types are forerunners of the later types having one or more axles under the firebox and they are enough out of line to make it necessary to add the dotted line *ab* to the chart to cover this group.

In the case of switching locomotives the entire weight of the engine is on drivers, hence the 0–6–0, 0–8–0 and 0–10–0 types compose another group which are considered with their tenders in order to indicate the range covered by these types.

The horsepower curves at the bottom of the chart are the same as the ones shown in last year's report except that some of the lines have been extended to cover a wider field. Some liberties have been taken in the case of future designs of locomotives in the higher horsepower range as indicated by the thin lines between 35 and 40 h.p. per ton on drivers. Tests have shown horsepower capacities in excess of 40 h.p. per ton on drivers have been reached, but in order to make use of the high capacity it is necessary to have exceptionally good rail conditions so as to avoid slipping at high speed.

The following example will illustrate how the horsepower capacity of typical steam locomotives can be determined from the weight of engine and the weight on drivers:

Example.—Find the cylinder and boiler capacities of the following locomotive:

Weight on drivers	122 tons
Weight of engine	182 tons
Weight of tender	140 tons
Total weight engine and tender	322 tons

Solution.—As described in the previous example, follow the horizontal line corresponding to 67 per cent (122/182) on the vertical scale to its intersection with the curve "Weight on Drivers", then the corresponding vertical line (40.75) to its intersections with the cylinder and boiler horsepower curves, then the corresponding horizontal lines to the vertical scale at the left and read 26.6 and 24.6 h.p. per ton on drivers for cylinder and boiler capacity, respectively.

The cylinder and boiler capacity of the typical locomotive will, therefore, be 26.6 and 24.6 times the weight on drivers (122 tons) or 3295 and 3000 h.p. respectively. The tables which are shown later will give the performance of the typical locomotive based on the horsepowers thus derived.

If the boiler pressure and diameter of pistons of the assumed locomotive are known, the cylinder horsepower of the locomotive can be computed by the following formulas based on Cole's ratios:

Simple Engines Using Superheated Steam

$$\text{Cyl. h.p.} = .0229 \times P \times A \text{ for two-cylinder engines.}$$
$$= .0343 \times P \times A \text{ for three-cylinder engines.}$$
$$= .0458 \times P \times A \text{ for four-cylinder engines.}$$

Where A = Area of one piston in square inches.
and P = Boiler pressure in pounds per square inch.

The boiler horsepower of a locomotive is equal to the pounds of water it can evaporate per hour divided by the pounds of steam required to produce a horsepower hour (20.8-lb.).

In order to determine the amount of water the boiler is capable of evaporating it is necessary to know the square feet of heating surface in the firebox and in tubes and flues. It is customary to assume the firebox will evaporate 55 pounds of water per square foot of heating surface per hour and the tubes and flues 8 to 10-lb. per square foot per hour, depending upon their dimensions and spacing. For example, assume the locomotive has 350 sq. ft. of heating surface in the firebox and 4300 sq. ft. in tubes and flues, then the pounds of water evaporated would be computed as follows:

Pounds of steam from firebox surface $55 \times 350 = 19{,}250$
Pounds of steam from tubes and flues $10 \times 4300 = 43{,}000$
Total 62,250
Boiler capacity equals 62,250/20.8 = 2,990 h.p.

On this basis the performance of the assumed locomotive will approximately equal the performance of the typical locomotive which can be obtained from the tables.

SUGGESTED FORM FOR CALCULATING
THE TRACTIVE EFFORT AND HORSEPOWER OUTPUT
AT THE RIM OF DRIVERS OF STEAM LOCOMOTIVES

SUPERHEATED STEAM

	Example
Weight on Drivers	122
Weight of Engine	182
Weight of Tender	140
Total Weight	322
Boiler Horsepower, Total	3000
Boiler Horsepower, per Ton on Drivers	24.6

Speed		Tractive Effort				Horsepower at Rim of Drivers	
		Per Ton on Drivers		Total			
V	M.P.H.	A	B	A	B	A	B
0	0	500	600				
1.00 V_1		480	580				
1.25"		463	522				
1.50 "		438	471				
1.75 "		410	428				
2.00 "		384	390				
2.25 "		357					
2.50 "		328					
2.75 "		302					
3.00 "		280					
3.25 "		260					
3.50 "		243					
3.75 "		227					
4.00 "		213					
4.50 "		188					
5.00 "		168					
6.00 "		138					
7.00 "		115					

A - Without Booster B - With Booster
Neglect weight on booster axle in all calculations)

V_1 = .395 x h.p. per ton on drivers.

$$\text{H.P. at Rim of Drivers} = \frac{\text{Total T.E. x M.P.H.}}{375}$$

Example:
First Line T.E. "A" = 500 x 122 = 61,000 "B" = 600 x 122 = 73,200.
Second Line M.P.H. = .395 x 24.6 = 9.72 T.E."A" = 480 x 122 = 58,560.
"B" = 70,760 H.P."A" = 58,560 x 9.72/375 = 1,519 "B" = 1,835.
Third Line M.P.H. = 1.25 x 9.72 = 12.15 T.E."A" = 463 x 122 = 56,486.
etc.

If the heating surface were less than assumed or the tubes and flues could only evaporate 8 pounds of water per square foot of heating surface, then its performance would be less than that given in the tables and adjustments would have to be made as described later.

Usually the next step after the boiler capacity has been determined is to compute the speed-tractive effort and speed horsepower characteristics of the locomotive. The form given below shows a simple arrangement for calculating the output at the rim of the drivers allowing 20-lb. per ton on drivers for engine friction. These characteristics can be applied to speed-time-energy calculations over any profile.

Some methods for calculating speed-time-energy curves make separate allowances for weight on drivers, and non-driver weight and for the resistance of the train. No such allowances should be made when using the characteristics obtained as indicated by the form. The resistance of the locomotive in pounds per ton is assumed to be the same as for the train, since the engine friction has been allowed for in obtaining the tractive effort at the rim of the drivers.

The train resistance assumed for various classes of trains in computing the tables is given immediately following:

Freight Train Resistance

(Pounds per Ton)

Class	*Av. Wt. Per Car*	*Miles per Hour* 10	15	20	25	30	35	40	45	50	60
Manifest	40	5.24	5.64	6.09	6.62	7.19	7.84	8.54	9.31	10.12	11.95
Coal and Ore ..	80	3.59	3.92	4.27	4.65	5.07	5.52	6.00	6.51	7.05	8.23
Empty Cars ...	20	8.56	9.12	9.79	10.60	11.53	12.58	13.75	15.06	16.48	19.69

The tables 1 to 9 inclusive on the following pages are for the purpose of showing the conditions which are necessary to obtain the maximum gross ton miles per hour and are the same as given in last year's report, except for a few corrections, but extended to cover locomotives having 50 and 60 per cent of their total weight on drivers. A set of tables covering future designs is also included.

In order to show the application of these tables a number of examples will be assumed:

Example.—Assume the same locomotive as used in the previous examples and find the speed and weight of train which will give the maximum gross ton miles per hour on a .2 per cent grade based on the train resistance of manifest trains.

Solution.—It has been shown that this locomotive corresponds to a typical locomotive having 40.75 per cent of its weight including tender on drivers. In the tables for manifest trains look for the group headed "Weight on Drivers" 40 per cent and opposite .2 per cent grade find the speed 29.6 m.p.h. and the weight of train 9.19 tons per ton of locomotive. As previously determined the weight of the typical locomotive is 300 tons hence the trailing weight which will produce the maximum gross ton miles per hour is 300 $\times$ 9.19 or 2757 tons. On account of the excess weight of tender assumed it is necessary to deduct 22 tons from 2757 leaving 2735 tons, as the correct tonnage for the assumed locomotive. The gross ton miles per hour then become 29.6 $\times$ 2735 or 80,956.

In this case it is an unnecessary refinement to correct for the difference between 40 and 40.75 per cent weight on drivers but in order to illustrate the principle the correct values of speed and train weight found by interpolation between the 40 and 45 per cent columns are 29.25 m.p.h. and 9.40 tons per ton of locomotive which gives (300 $\times$ 9.40 $\times$ 29.25) or 82,485 gross ton miles per hour for the typical locomotive and 81,842 for the assumed locomotive adjusted for excess weight of tender and for the difference in percentage of weight on drivers.

Table 1

CONDITIONS FOR OBTAINING MAXIMUM GROSS TON MILES PER HOUR
FOR VARIOUS CLASSES OF LOCOMOTIVES ON VARIOUS GRADES.

MANIFEST TRAINS

	Weight on Drivers 30%				Weight on Drivers 35%				Weight on Drivers 40%				
Per Cent Grade	Miles per Hour	Trailing Tons Per Ton of Loco. A (11.85)	Trailing Tons Per Ton of Loco. B	G.T.M. Per Hr. Per Ton of Loco.	Miles per Hour	Trailing Tons Per Ton of Loco. A (10.86)	Trailing Tons Per Ton of Loco. B	G.T.M. Per Hr. Per Ton of Loco.	Miles per Hour	Trailing Tons Per Ton of Loco. A (9.88)	Trailing Tons Per Ton of Loco. B	G.T.M. Per Hr. Per Ton of Loco.	Per Cent Grade
- .1	37.3		12.06	450	35.3		14.45	510	32.9		16.87	555	- .1
0	35.8	26.83	9.64	345	33.9	31.96	11.30	383	31.7	37.24	13.09	415	0
.1	34.3	19.30	7.87	270	32.6	22.94	9.29	303	30.6	26.66	10.78	330	.1
.2	33.0	14.97	6.76	223	31.4	17.80	7.96	250	29.6	20.67	9.19	272	.2
.3	31.7	12.17	5.90	187	30.4	14.47	6.91	210	28.7	16.81	8.01	230	.3
.4	30.7	10.20	5.21	160	29.4	12.15	6.12	180	27.8	14.12	7.19	195	.4
.5	29.7	8.75	4.71	140	28.5	10.43	5.44	155	27.0	12.13	6.30	170	.5
.6	28.8	7.63	4.27	123	27.7	9.11	4.98	138	26.3	10.61	5.70	150	.6
.7	27.9	6.74	3.94	110	26.9	8.06	4.50	121	25.6	9.40	5.16	132	.7
.8	27.1	6.01	3.62	98	26.2	7.21	4.16	109	24.9	8.42	4.70	117	.8
.9	26.3	5.41	3.35	88	25.5	6.51	3.80	97	24.3	7.61	4.40	107	.9
1.0	25.6	4.91	3.13	80	24.9	5.91	3.57	89	23.7	6.93	4.09	97	1.0
1.2	24.3	4.10	2.72	66	23.7	4.97	3.16	75	22.7	5.84	3.66	83	1.2
1.4	23.1	3.49	2.42	56	22.7	4.25	2.86	65	21.7	5.02	3.27	71	1.4
1.6	22.1	3.01	2.17	48	21.7	3.69	2.53	55	20.9	4.37	2.97	62	1.6
1.8	21.1	2.62	1.99	42	20.8	3.24	2.27	48	20.1	3.85	2.74	55	1.8
2.0	20.1	2.30	1.79	36	20.0	2.86	2.15	43	19.4	3.42	2.53	49	2.0
2.2	19.3	2.04	1.66	32	19.2	2.55	1.98	38	18.7	3.06	2.35	44	2.2
2.4	18.5	1.81	1.51	28	18.4	2.28	1.85	34	18.1	2.76	2.21	40	2.4

TABLE 2

MANIFEST TRAINS

Per Cent Grade	Weight on Drivers 45%				Weight on Drivers 50%				Weight on Drivers 60%				Per Cent Grade
	Miles per Hour	Trailing Tons Per Ton of Loco.		G.T.M. Per Hr. Per Ton of Loco.	Miles per Hour	Trailing Tons Per Ton of Loco.		G.T.M. Per Hr. Per Ton of Loco.	Miles per Hour	Trailing Tons Per Ton of Loco.		G.T.M. Per Hr. Per Ton of Loco.	
		A (8.89)	B			A (7.90)	B			A (5.93)	B		
- .1	30.2		20.40	616	27.3		24.00	655	21.1		33.20	700	- .1
0	29.1	42.60	15.64	455	26.4	48.10	18.00	475	20.4	59.10	22.80	465	0
.1	28.1	30.42	12.56	353	25.5	34.20	14.31	365	19.8	41.90	17.93	355	.1
.2	27.3	23.56	10.62	290	24.8	26.50	11.90	295	19.3	32.37	15.02	290	.2
.3	26.5	19.16	9.17	243	24.1	21.55	10.00	241	18.8	27.30	12.60	237	.3
.4	25.7	16.10	7.86	202	23.5	18.10	8.89	209	18.3	22.10	10.81	198	.4
.5	25.0	13.84	7.00	175	22.8	15.57	7.89	180	17.9	19.01	9.72	174	.5
.6	24.3	12.11	6.26	152	22.3	13.64	7.08	158	17.5	16.65	8.68	152	.6
.7	23.7	10.74	5.74	136	21.8	12.10	6.51	142	17.1	14.80	7.89	135	.7
.8	23.2	9.63	5.17	120	21.3	10.86	6.01	128	16.7	13.29	7.18	120	.8
.9	22.7	8.72	4.93	112	20.8	9.83	5.58	116	16.4	12.05	6.71	110	.9
1.0	22.2	7.94	4.59	102	20.4	8.96	5.19	106	16.1	11.00	6.21	100	1.0
1.2	21.2	6.72	4.06	86	19.6	7.60	4.59	90	15.5	9.35	5.16	80	1.2
1.4	20.4	5.79	3.68	75	18.9	6.55	4.07	77	14.9	8.10	4.77	71	1.4
1.6	19.5	5.05	3.33	65	18.2	5.74	3.68	67	14.4	7.11	4.31	62	1.6
1.8	18.8	4.47	3.03	57	17.5	5.08	3.32	58	14.0	6.32	3.93	55	1.8
2.0	18.2	3.98	2.75	50	16.9	4.54	3.02	51	13.6	5.66	3.60	49	2.0
2.2	17.6	3.58	2.61	46	16.4	4.09	2.80	46	13.2	5.13	3.33	44	2.2
2.4	17.0	3.23	2.41	41	15.9	3.71	2.64	42	12.8	4.66	3.05	39	2.4

"TRAILING TONS "A" The tonnages shown in the "A" column are based upon a tractive effort equal to 25 per cent of the weight on drivers. The corresponding speed in m.p.h. is shown in parenthesis at the head of the column. The gross ton miles obtainable under MAXIMUM TONNAGE conditions is the product of the tonnage and miles per hour just referred to."

"TRAILING TONS "B" The tonnages shown in the "B" column give the weight necessary to obtain the maximum gross ton miles per hour. The speeds and gross ton miles per hour corresponding to any grade will be found under the proper headings."

TABLE 3

COAL AND ORE TRAINS

Per Cent Grade	Weight on Drivers 30%				Weight on Drivers 35%				Weight on Drivers 40%				Per Cent Grade
	Miles per Hour	Trailing Tons Per Ton of Loco.		G.T.M. Per Hr. Per Ton of Loco.	Miles per Hour	Trailing Tons Per Ton of Loco.		G.T.M. Per Hr. Per Ton of Loco.	Miles per Hour	Trailing Tons Per Ton of Loco.		G.T.M. Per Hr. Per Ton of Loco.	
		A (11.85)	B			A (10.86)	B			A (9.88)	B		
.1	39.6		17.68	700	37.2		21.77	810	34.6		35.80	1240	- .1
0	37.7	39.43	12.87	485	35.5	46.95	15.07	535	33.1	54.87	20.69	685	0
.1	36.0	25.27	9.86	355	34.0	29.97	11.53	392	31.8	34.84	13.21	420	.1
.2	34.5	18.46	8.12	280	32.7	21.88	9.48	310	30.7	25.39	11.08	340	.2
.3	33.2	14.45	6.93	230	31.5	17.13	8.10	255	29.6	19.88	9.19	272	.3
.4	31.9	11.81	6.02	192	30.5	14.02	7.05	215	28.6	16.27	7.87	225	.4
.5	30.8	9.94	5.29	163	29.5	11.82	6.17	182	27.7	13.73	6.86	190	.5
.6	29.8	8.55	4.73	141	28.6	10.15	5.52	158	26.9	11.84	6.21	167	.6
.7	28.9	7.47	4.33	125	27.8	8.92	5.00	139	26.2	10.38	5.65	148	.7
.8	28.0	6.61	3.96	111	27.0	7.91	4.56	123	25.6	9.21	5.16	132	.8
.9	27.1	5.91	3.62	98	26.3	7.08	4.18	110	25.0	8.27	4.80	120	.9
1.0	26.3	5.33	3.35	88	25.6	6.40	3.89	99	24.4	7.48	4.43	109	1.0
1.2	24.9	4.41	2.89	72	24.3	5.33	3.33	81	23.2	6.25	3.88	90	1.2
1.4	23.7	3.73	2.53	60	23.2	4.53	2.97	69	22.1	5.33	3.39	75	1.4
1.6	22.6	3.20	2.30	52	22.1	3.91	2.62	58	21.3	4.62	3.14	67	1.6
1.8	21.5	2.78	2.09	45	21.2	3.41	2.41	51	20.4	4.05	2.84	58	1.8
2.0	20.5	2.43	1.90	39	20.3	3.01	2.22	45	19.6	3.59	2.55	50	2.0
2.2	19.6	2.14	1.73	34	19.5	2.67	2.05	40	18.9	3.20	2.38	45	2.2
2.4	18.8	1.90	1.60	30	18.7	2.39	1.87	35	18.2	2.88	2.20	40	2.4

TABLE 4

COAL AND ORE TRAINS

Per Cent Grade	Weight on Drivers 45%				Weight on Drivers 50%				Weight on Drivers 60%				Per Cent Grade
	Miles per Hour	Trailing Tons Per Ton of Loco.		G.T.M. Per Hr. Per Ton of Loco.	Miles per Hour	Trailing Tons Per Ton of Loco.		G.T.M. Per Hr. Per Ton of Loco.	Miles per Hour	Trailing Tons Per Ton of Loco.		G.T.M. Per Hr. Per Ton of Loco.	
		A (8.89)	B			A (7.90)	B			A (5.93)	B		
- .1	31.5				28.4		38.70	1,100	21.6				- .1
0	30.2	62.92	20.20	610	27.3	71.20	24.00	655	21.0	88.25	30.95	650	0
.1	29.1	39.77	15.64	455	26.3	44.75	17.60	463	20.3	55.00	21.93	445	.1
.2	28.1	28.92	12.56	353	25.5	32.50	14.31	365	19.7	39.75	17.52	345	.2
.3	27.2	22.64	10.40	283	24.8	25.40	11.90	295	19.2	31.10	14.48	278	.3
.4	26.4	18.53	8.95	237	24.1	20.80	10.00	241	18.7	25.40	12.30	230	.4
.5	25.7	15.64	7.86	202	23.4	17.56	8.68	203	18.2	21.45	10.55	192	.5
.6	25.0	13.50	7.00	175	22.8	15.15	7.90	168	17.5	18.53	9.43	168	.6
.7	24.4	11.84	6.39	156	22.2	13.31	6.93	154	17.4	16.26	8.50	148	.7
.8	23.8	10.53	5.84	139	21.7	11.84	6.45	140	17.0	14.50	7.64	130	.8
.9	23.2	9.46	5.38	123	21.2	10.65	5.94	126	16.7	13.05	7.18	120	.9
1.0	22.6	8.57	4.89	110	20.8	9.65	5.58	116	16.4	11.85	6.71	110	1.0
1.2	21.6	7.18	4.26	92	19.9	8.11	4.83	98	15.8	9.96	5.82	92	1.2
1.4	20.7	6.14	3.77	78	19.1	6.94	4.24	81	15.2	8.56	5.07	77	1.4
1.6	19.9	5.33	3.47	69	18.4	6.05	3.81	70	14.7	7.48	4.56	67	1.6
1.8	19.2	4.69	3.18	61	17.8	5.33	3.48	62	14.2	6.62	4.08	58	1.8
2.0	18.5	4.17	2.92	54	17.1	4.78	3.16	54	13.8	5.92	3.77	52	2.0
2.2	17.9	3.94	2.74	49	16.6	4.27	2.89	48	13.4	5.34	3.50	47	2.2
2.4	17.3	3.37	2.49	43	16.1	3.86	2.67	43	13.0	4.84	3.23	42	2.4

"TRAILING TONS "A" The tonnages shown in the "A" column are based upon a tractive effort equal to 25 per cent of the weight on drivers. The corresponding speed in m.p.h. is shown in parenthesis at the head of the column. The gross ton miles obtainable under MAXIMUM TONNAGE conditions is the product of the tonnage and miles per hour just referred to."

"TRAILING TONS "B" The tonnages shown in the "B" column give the weight necessary to obtain the **maximum gross ton** miles per hour. The speeds and gross ton miles per hour corresponding to any grade will be found under the proper headings."

TABLE 5

EMPTY TRAINS

Per Cent Grade	Weight on Drivers 30%				Weight on Drivers 35%				Weight on Drivers 40%				Per Cent Grade
	Miles per Hour	Trailing Tons Per Ton of Loco.		G.T.M. Per Hr. Per Ton of Loco.	Miles per Hour	Trailing Tons Per Ton of Loco.		G.T.M. Per Hr. Per Ton of Loco.	Miles per Hour	Trailing Tons Per Ton of Loco.		G.T.M. Per Hr. Per Ton of Loco.	
		A(11.85)	B			A (10.86)	B			A (9.88)	B		
- .4	38.1		13.71	522	36.4		17.99	655					- .4
- .3	36.6		10.79	395	34.8		13.22	460	32.7		16.06	525	- .3
- .2	35.1		8.75	307	33.3		10.36	345	31.4		12.58	395	- .2
- .1	33.9		7.53	255	32.2		8.85	285	30.3		10.23	310	- .1
0	32.7	16.10	6.58	215	31.1	19.21	7.65	238	29.4	22.39	8.84	260	0
.1	31.5	12.93	5.75	181	30.2	15.42	6.72	203	28.5	17.96	7.79	222	.1
.2	30.5	10.75	5.15	157	29.3	12.82	6.01	176	27.7	14.94	6.93	192	.2
.3	29.5	9.16	4.61	136	28.5	10.94	5.44	155	26.9	12.75	6.13	165	.3
.4	28.6	7.94	4.23	121	27.7	9.50	4.95	137	26.2	11.08	5.65	148	.4
.5	27.8	6.99	3.89	108	26.9	8.38	4.50	121	25.5	9.78	5.10	130	.5
.6	27.0	6.22	3.59	97	26.2	7.47	4.16	109	24.9	8.73	4.70	117	.6
.7	26.3	5.59	3.35	88	25.5	6.72	3.80	97	24.3	7.87	4.40	107	.7
.8	25.6	5.06	3.13	80	24.9	6.10	3.57	89	23.7	7.15	4.09	97	.8
.9	24.9	4.60	2.89	72	24.3	5.56	3.33	81	23.2	6.53	3.88	90	.9
1.0	24.3	4.21	2.72	66	23.8	5.11	3.15	75	22.7	6.01	3.66	83	1.0
1.2	23.2	3.58	2.46	57	22.7	4.36	2.86	65	21.8	5.14	3.30	72	1.2
1.4	22.1	3.08	2.17	48	21.8	3.77	2.57	56	20.9	4.47	2.97	62	1.4
1.6	21.1	2.68	1.99	42	20.9	3.30	2.34	49	20.1	3.93	2.74	55	1.6
1.8	20.2	2.35	1.83	37	20.0	2.92	2.15	43	19.4	3.49	2.53	49	1.8
2.0	19.3	2.08	1.66	32	19.2	2.60	1.98	38	18.7	3.12	2.35	44	2.0
2.2	18.5	1.84	1.51	28	18.4	2.32	1.79	33	18.0	2.81	2.17	39	2.2
2.4	17.7	1.64	1.41	25	17.8	2.09	1.69	30	17.4	2.54	2.01	35	2.4

TABLE 6

EMPTY TRAINS

Per Cent Grade	Weight on Drivers 45%				Weight on Drivers 50%				Weight on Drivers 60%				Per Cent Grade
	Miles per Hour	Trailing Tons Per Ton of Loco.		G.T.M. Per Hr. Per Ton of Loco.	Miles per Hour	Trailing Tons Per Ton of Loco.		G.T.M. Per Hr. Per Ton of Loco.	Miles per Hour	Trailing Tons Per Ton of Loco.		G.T.M. Per Hr. Per Ton of Loco.	
		A (8.89)	B			A (7.90)	B			A (5.93)	B		
- .4	31.2				28.1		33.63	945	22.0				- .4
- .3	30.0		19.33	580	27.1		22.50	610	21.2		35.40	750	- .3
- .2	29.0		15.28	443	26.2		17.18	450	20.5		23.90	490	- .2
- .1	28.0		12.25	343	25.4		13.78	350	19.9		18.60	370	- .1
0	27.2	25.60	10.40	283	24.7	28.75	11.66	288	19.4	35.35	15.46	300	0
.1	26.4	20.51	8.98	237	24.1	22.15	10.00	241	18.9	28.25	13.07	247	.1
.2	25.7	17.06	7.86	202	23.4	19.15	8.72	204	18.4	23.50	11.14	205	.2
.3	25.0	14.56	7.00	175	22.8	16.35	7.89	180	18.0	20.05	9.89	178	.3
.4	24.4	12.67	6.39	156	22.3	14.25	7.08	158	17.6	17.46	8.98	158	.4
.5	23.8	11.19	5.84	139	21.8	12.58	6.51	142	17.2	15.44	8.14	140	.5
.6	23.2	10.00	5.34	124	21.3	11.25	6.01	128	16.8	13.81	7.32	123	.6
.7	22.7	9.02	4.93	112	20.8	10.16	5.58	116	16.5	12.49	6.79	112	.7
.8	22.2	8.20	4.59	102	20.4	9.25	5.20	106	16.2	11.38	6.29	102	.8
.9	21.7	7.50	4.29	93	20.0	8.47	4.90	98	15.9	10.42	5.91	94	.9
1.0	21.2	6.91	4.01	85	19.6	7.80	4.58	90	15.6	9.61	5.45	85	1.0
1.2	20.4	5.93	3.68	75	18.8	6.72	4.04	76	15.1	8.30	4.97	75	1.2
1.4	19.6	5.17	3.32	65	18.1	5.87	3.65	66	14.6	7.28	4.45	65	1.4
1.6	18.9	4.56	3.07	58	17.5	5.19	3.31	58	14.1	6.45	4.04	57	1.6
1.8	18.3	4.06	2.79	51	16.9	4.63	3.04	51	13.7	5.78	3.65	50	1.8
2.0	17.7	3.64	2.60	46	16.4	4.17	2.80	46	13.3	5.22	3.38	45	2.0
2.2	17.1	3.29	2.46	42	15.9	3.77	2.64	42	12.9	4.75	3.10	40	2.2
2.4	16.6	2.99	2.30	38	15.4	3.43	2.47	38	12.5	4.33	2.88	36	2.4

"TRAILING TONS "A" The tonnages shown in the "A" column are based upon a tractive effort equal to 25 per cent of the weight on drivers. The corresponding speed in m.p.h. is shown in parenthesis at the head of the column. The gross ton miles obtainable under MAXIMUM TONNAGE conditions is the product of the tonnage and miles per hour just referred to."

"TRAILING TONS "B" The tonnages shown in the "B" column give the weight necessary to obtain the maximum gross ton miles per hour. The speeds and gross ton miles per hour corresponding to any grade will be found under the proper headings."

TABLE 7

FUTURE DESIGNS

MANIFEST TRAINS.

Per Cent Grade	Weight on Drivers *30%				Weight on Drivers 35%				Weight on Drivers 40%				Per Cent Grade
	Miles per Hour	Trailing Tons Per Ton of Loco.		G.T.M. Per Hr. Per Ton of Loco.	Miles per Hour	Trailing Tons Per Ton of Loco.		G.T.M. Per Hr. Per Ton of Loco.	Miles per Hour	Trailing Tons Per Ton of Loco.		G.T.M. Per Hr. Per Ton of Loco.	
		A (15.80)	B			A (13.62)	B			A (11.46)	B		
- .1	47.6		9.73	465	43.1		12.24	527	37.7		15.91	600	- .1
.0	46.0	25.25	7.74	375	41.5	30.64	10.07	418	36.3	36.30	12.40	450	0
.1	44.3	18.45	7.00	310	40.0	22.25	8.45	338	35.1	26.15	10.31	362	.1
.2	42.8	14.45	6.12	262	38.7	17.37	7.36	285	33.9	20.35	8.70	295	.2
.3	41.4	11.80	5.43	225	37.5	14.17	6.58	247	32.8	16.60	7.56	248	.3
.4	40.1	9.94	4.86	195	36.3	11.93	5.92	215	31.9	13.95	6.74	215	.4
.5	38.9	8.54	4.42	172	35.3	10.26	5.32	188	31.0	12.02	5.97	185	.5
.6	37.6	7.46	4.07	153	34.3	8.98	4.81	165	30.2	10.52	5.40	163	.6
.7	36.5	6.60	3.75	137	33.4	7.95	4.40	147	29.4	9.33	4.93	145	.7
.8	35.5	5.90	3.46	123	32.5	7.12	4.03	131	28.7	8.36	4.56	131	.8
.9	34.5	5.32	3.27	113	31.7	6.43	3.78	120	28.0	7.56	4.21	118	.9
1.0	33.6	4.83	3.03	102	30.9	5.85	3.53	109	27.3	6.88	3.96	108	1.0
1.2	32.0	4.05	2.66	85	29.5	4.92	3.19	94	26.2	5.81	3.55	93	1.2
1.4	30.5	3.45	2.39	73	28.2	4.22	2.84	80	25.1	4.99	3.19	80	1.4
1.6	29.1	2.98	2.16	63	27.0	3.66	2.59	70	24.0	4.35	2.87	69	1.6
1.8	27.8	2.59	1.94	54	25.9	3.22	2.32	60	23.1	3.83	2.64	61	1.8
2.0	26.6	2.28	1.77	47	24.9	2.84	2.13	53	22.3	3.41	2.47	55	2.0
2.2	25.5	2.02	1.65	42	23.9	2.53	1.92	46	21.5	3.05	2.28	49	2.2
2.4	24.6	1.79	1.50	37	23.0	2.27	1.83	42	20.7	2.75	2.13	44	2.4

* Adhesion Limits may prevent the application of 40 HP per ton on Drivers, hence the performance listed under 30 per cent weight on drivers is doubtful.

TABLE 8

FUTURE DESIGNS

COAL & ORE TRAINS

Per Cent Grade	Weight on Drivers *30%				Weight on Drivers 35%				Weight on Drivers 40%				Per Cent Grade
	Miles per Hour	Trailing Tons Per Ton of Loco.		G.T.M. Per Hr. Per Ton of Loco.	Miles per Hour	Trailing Tons Per Ton of Loco.		G.T.M. Per Hr. Per Ton of Loco.	Miles per Hour	Trailing Tons Per Ton of Loco.		G.T.M. Per Hr. Per Ton of Loco.	
		A(15.80)	B			A (13.62)	B			A (11.46)	B		
- .1	51.1		14.09	720	45.7		16.96	775	39.5		24.05	950	- .1
0	48.8	36.70	10.75	525	43.6	44.70	13.07	570	37.9	53.20	18.58	628	0
.1	46.7	24.08	8.72	407	41.9	35.25	10.81	442	36.5	34.15	12.82	468	.1
.2	44.9	17.80	7.34	330	40.3	21.35	8.71	351	35.2	25.00	10.45	368	.2
.3	43.4	14.03	6.45	280	38.9	16.80	7.53	293	34.0	19.64	8.97	305	.3
.4	41.9	11.52	5.65	237	37.6	13.80	6.65	250	33.0	16.10	7.72	255	.4
.5	40.5	9.73	5.06	205	36.5	11.65	6.03	220	32.0	13.60	6.78	217	.5
.6	39.1	8.39	4.48	175	35.4	10.05	5.37	190	31.0	11.75	5.97	185	.6
.7	37.9	7.34	4.12	156	34.4	8.81	4.88	168	30.2	10.30	5.43	164	.7
.8	36.8	6.50	3.80	140	33.5	7.82	4.45	149	29.4	9.16	4.93	145	.8
.9	35.7	5.82	3.53	126	32.7	7.01	4.13	135	28.7	8.22	4.56	131	.9
1.0	34.7	5.25	3.31	115	31.9	6.34	3.82	122	28.0	7.44	4.25	119	1.0
1.2	32.9	4.36	2.86	94	30.3	5.29	3.40	103	26.8	6.22	3.77	101	1.2
1.4	31.3	3.69	2.56	80	28.9	4.50	3.01	87	25.6	5.31	3.36	86	1.4
1.6	29.8	3.17	2.28	68	27.6	3.88	2.68	74	24.6	4.61	3.05	75	1.6
1.8	28.5	2.75	2.07	59	26.5	3.39	2.45	65	23.6	4.04	2.84	67	1.8
2.0	27.2	2.41	1.84	50	25.4	2.99	2.20	56	22.7	3.58	2.56	58	2.0
2.2	26.0	2.12	1.69	44	24.4	2.66	2.01	49	21.9	3.19	2.33	51	2.2
2.4	25.0	1.88	1.56	39	23.5	2.38	1.87	44	21.1	2.87	2.18	46	2.4

* Adhesion Limits may prevent the application of 40 HP per ton on Drivers, hence the performance listed under 30 per cent weight on drivers is doubtful.

TABLE 9

FUTURE DESIGNS

EMPTY TRAINS

Per Cent Grade	Weight on Drivers *30%				Weight on Drivers 35%				Weight on Drivers 40%				Per Cent Grade
	Miles per Hour	Trailing Tons Per Ton of Loco.		G.T.M. Per Hr. Per Ton of Loco.	Miles per Hour	Trailing Tons Per Ton of Loco.		G.T.M. Per Hr. Per Ton of Loco.	Miles per Hour	Trailing Tons Per Ton of Loco.		G.T.M. Per Hr. Per Ton of Loco.	
		A (15.80)	B			A (13.62)	B			A (11.46)	B		
- .4	47.7		9.65	460	43.6		13.08	570	38.4		18.23	700	- .4
- .3	46.2		8.29	383	42.1		10.81	455	37.1		14.15	525	- .3
- .2	44.7		7.22	323	40.6		9.06	368	35.8		11.45	410	- .2
- .1	43.2		6.37	275	39.4		7.92	312	34.6		9.54	330	- .1
0	41.9	15.25	5.92	248	38.2	18.50	7.01	268	33.6	22.00	8.33	280	0
.1	40.6	12.35	5.07	206	37.1	14.95	6.33	235	32.6	17.72	7.36	240	.1
.2	39.4	10.34	4.57	180	36.0	12.49	5.69	205	31.7	14.76	6.53	207	.2
.3	38.3	8.84	4.20	161	35.0	10.69	5.14	180	30.9	12.62	5.86	181	.3
.4	37.1	7.70	3.91	145	34.0	9.31	4.68	159	30.0	10.99	5.27	158	.4
.5	36.1	6.80	3.66	132	33.1	8.22	4.29	142	29.3	9.70	4.85	142	.5
.6	35.2	6.06	3.41	120	32.3	7.34	3.97	128	28.6	8.67	4.51	129	.6
.7	34.3	5.46	3.21	110	31.5	6.61	3.72	117	27.9	7.81	4.23	118	.7
.8	33.5	4.94	3.02	101	30.8	6.01	3.51	108	27.3	7.10	3.96	108	.8
.9	32.7	4.51	2.84	93	30.1	5.49	3.32	100	26.7	6.49	3.75	100	.9
1.0	31.9	4.13	2.67	85	29.4	5.04	3.16	93	26.1	5.97	3.56	93	1.0
1.2	30.4	3.51	2.37	72	28.1	4.31	2.81	79	25.1	5.12	3.19	80	1.2
1.4	29.1	3.03	2.17	63	27.0	3.73	2.56	69	24.1	4.45	2.91	70	1.4
1.6	27.8	2.64	1.96	55	25.9	3.27	2.32	60	23.1	3.92	2.64	61	1.6
1.8	26.6	2.32	1.81	48	24.9	2.89	2.13	53	22.3	3.46	2.47	55	1.8
2.0	25.5	2.05	1.66	42	23.9	2.58	1.93	46	21.5	3.11	2.28	49	2.0
2.2					23.0	2.30	1.83	42	20.7	2.74	2.12	44	2.2
2.4					22.2	2.07	1.71	36	20.1	2.55	1.99	40	2.4

* Adhesion Limits may prevent the application of 40 HP per ton on Drivers, hence the performance listed under 30 per cent weight on drivers is doubtful.

To correct for small differences in boiler capacities assume the train weight remains constant and the speed is proportional to the boiler capacities. If there is a wide difference in boiler capacities the effect of differences in train resistance will be appreciable tending to increase or decrease the weight of train depending on whether the boiler capacities are less or greater than for the typical locomotive. Likewise the speed will be less than proportional to the horsepower capacities. For example, compare the tables for future designs of locomotives with normal designs column for column.

Having three classes of trains, adjustment can be made for differences in train resistance by interpolating between tables. Another way to correct for differences in train resistance is to express the difference in terms of grade, thus 2 pounds per ton difference in train resistance is equivalent to .1 per cent grade. The performance on level track would therefore correspond to that shown on a + .1 or a — .1 per cent grade, depending on whether the train resistance was 2 pounds per ton greater or less than assumed in Table 1 on page 895.

The trailing tons shown in column headed "A", Tables 2, 3 and 4, are the maximum tonnages which can be hauled on the various grades, assuming the locomotive is capable of exerting a tractive effort equal to 25 per cent of the weight on drivers. If the locomotive is equipped with a booster of auxiliary engine it may be able to start on the grades with the tonnages shown. If the engine is not equipped with a booster or auxiliary engine, it will only be able to negotiate short grades with the tonnages shown.

By comparing the tonnages in the "A" and "B" columns, it is possible to determine whether or not a locomotive can be loaded heavy enough on ruling grades to obtain the maximum gross ton miles per hour over some lower grades. Take, for example, the typical locomotive previously described. The weight of train which will give the maximum gross ton miles per hour on a .2 per cent grade has been shown to be 9.19 times the weight of the locomotive, including tender. This is slightly less than 9.40 found in the "A" column of the same table corresponding to a .7 per cent grade. If the ruling grade on the profile is .7 per cent or less, then it will be possible to operate a heavy enough train to produce the maximum gross ton miles per hour on a .2 per cent grade. If the ruling grade is greater than .7 per cent the tonnage which can be hauled will be limited by the ruling grade to something less than required to obtain the maximum gross ton miles per hour on a .2 per cent grade. In general, if the ruling grade is not more than .5 per cent greater than the average grade, then the profile will not limit the train weight below that required to obtain the maximum gross ton miles per hour on the average grade.

The speed in miles per hour corresponding to the maximum tonnages ("A" column) is given in parenthesis at the head of Column "A".

(II) Comparison of Freight Train and Yard Performances

The purpose of this discussion in connection with the Committee's assignment is to study the effect of operating long or heavy freight trains upon yard switching performance. The present investigation is limited to a preliminary study of general statistics which may be extended later to specific cases.

A summary of statistics relating to freight train and yard performances for railroads in the United States by districts is given in Table 1 and plotted in Fig. 2, 3, 4 and 5. The table and charts show in some instances that the locomotive hours in freight switching service exceed the train hours on the road, or in other words, the work done in switching freight trains often requires more crew time than required to run them 100 miles on the road.

Table 1

Railroads in the United States Comparison of Road and Yard Performances, by Districts

ALL DISTRICTS

1,000 Freight Train Miles	Million Gross Ton Miles Excl. Loco.	Train Hours	Switch. Loco. Hours	Aver. Train Weight Tons	Hrs. Per 100 Train Miles Rd.Time	Hours Per 100,000 Gross Ton Miles: Road Time	Hours Per 100,000 Gross Ton Miles: Sw.Loco. Hours	Year
530,141	760,716	45,949,610	40,411,906	1,435	8.67	6.04	5.31	1921
554,780	813,052	50,148,349	43,664,477	1,466	9.04	6.17	5.37	1922
641,556	987,384	58,885,143	53,216,135	1,429	9.18	5.97	5.39	1923
600,675	953,963	52,239,512	48,738,631	1,588	8.71	5.48	5.11	1924
612,865	1,023,490	52,010,380	50,105,330	1,670	8.49	5.09	4.90	1925
632,557	1,098,692	53,064,819	52,581,844	1,737	8.39	4.83	4.79	1926
610,497	1,086,829	49,525,815	49,943,376	1,780	8.11	4.55	4.60	1927
601,648	1,105,506	46,740,784	48,785,424	1,837	7.77	4.23	4.42	1928
611,919	1,141,619	46,496,855	50,743,084	1,866	7.60	4.07	4.44	1929
538,064	1,006,446	38,945,349	43,490,772	1,870	7.24	3.87	4.32	1930
464,217	839,743	31,451,064	35,562,243	1,809	6.78	3.75	4.23	1931
390,591	657,208	25,215,416		1,683	6.45	3.84		1932

EASTERN DISTRICT

1,000 Freight Train Miles	Million Gross Ton Miles Excl. Loco.	Train Hours	Switch. Loco. Hours	Aver. Train Weight Tons	Hrs. Per 100 Train Miles Rd.Time	Hours Per 100,000 Gross Ton Miles: Road Time	Hours Per 100,000 Gross Ton Miles: Sw.Loco. Hours
198,960	322,391	18,475,787	20,126,794	1,620	9.28	5.73	6.24
209,798	339,559	20,392,136	22,238,396	1,619	9.72	6.00	6.55
250,832	427,484	25,144,826	28,225,653	1,704	10.02	5.98	6.60
227,375	392,633	21,117,621	24,950,248	1,723	9.27	5.38	6.35
232,078	417,479	20,843,115	25,551,693	1,799	8.98	4.99	6.12
244,116	451,236	21,872,621	27,209,316	1,843	8.95	4.85	6.03
231,176	440,454	19,848,600	25,372,357	1,905	8.59	4.51	5.76
221,161	443,364	18,164,533	24,657,696	2,005	8.21	4.10	5.56
226,157	463,635	18,169,766	26,071,748	2,050	8.03	3.92	5.61
193,931	398,405	14,892,473	21,865,279	2,054	7.68	3.73	5.49
166,648	333,697	11,957,156	17,694,606	2,002	7.18	3.58	5.31
138,736	262,792	9,533,578		1,894	6.88	3.63	

SOUTHERN DISTRICT

1,000 Freight Train Miles	Million Gross Ton Miles Excl. Loco.	Train Hours	Switch. Loco. Hours	Aver. Train Weight Tons	Hrs. Per 100 Train Miles Rd.Time	Hours Per 100,000 Gross Ton Miles: Road Time	Hours Per 100,000 Gross Ton Miles: Sw.Loco. Hours	Year
104,219	142,675	8,853,838	6,420,172	1,369	8.50	6.21	4.50	1921
113,080	160,714	10,095,290	7,025,032	1,421	8.93	6.28	4.37	1922
129,848	189,941	11,593,253	8,335,903	1,463	8.93	6.14	4.39	1923
126,953	193,787	10,836,202	7,942,710	1,526	8.54	5.59	4.10	1924
134,988	217,669	11,417,397	8,522,376	1,613	8.46	5.25	3.92	1925
139,491	237,597	11,563,806	8,954,686	1,703	8.29	4.87	3.77	1926
120,876	229,461	10,362,723	8,325,153	1,753	7.92	4.52	3.63	1927
124,814	220,542	9,417,821	7,740,775	1,767	7.55	4.27	3.51	1928
125,095	226,204	9,192,096	7,713,719	1,808	7.35	4.06	3.41	1929
113,609	205,728	8,001,309	6,948,963	1,811	7.04	3.89	3.38	1930
99,558	173,640	6,583,778	5,918,886	1,744	6.61	3.79	3.41	1931
81,038	135,811	5,161,048		1,676	6.37	3.80		1932

WESTERN DISTRICT

1,000 Freight Train Miles	Million Gross Ton Miles Excl. Loco.	Train Hours	Switch. Loco. Hours	Aver. Train Weight Tons	Hrs. Per 100 Train Miles Rd.Time	Hours Per 100,000 Gross Ton Miles: Road Time	Hours Per 100,000 Gross Ton Miles: Sw.Loco. Hours
224,653	295,286	16,589,392	13,864,940	1,314	9.27	6.30	4.70
231,581	312,346	19,636,122	14,401,049	1,349	8.48	6.29	4.62
260,623	369,658	22,116,697	16,654,580	1,415	8.49	5.99	4.51
245,756	367,529	20,293,247	15,845,674	1,496	8.26	5.52	4.31
245,787	388,265	19,748,025	16,031,262	1,580	8.03	5.08	4.13
248,948	409,307	19,628,392	16,417,842	1,646	7.89	4.79	4.01
248,145	416,914	19,313,412	16,245,870	1,676	7.78	4.63	3.90
255,673	441,620	19,158,430	16,386,954	1,727	7.54	4.34	3.71
230,667	451,780	19,154,936	16,957,618	1,733	7.34	4.23	3.75
236,824	402,313	16,851,862	14,884,630	1,745	6.96	3.99	3.65
198,211	332,406	12,910,156	11,948,751	1,679	6.52	3.83	3.59
170,817	288,605	10,815,790		1,514	6.16	4.07	

While this may not be a true measure of yard switching performance, it is nevertheless a condition which ought to attract considerable attention. It may be that Freight Train and Yard Performances are not strictly comparable, but it is logical to assume that on most railroads there is a tie between the two services when conditions are balanced.

The Association is familiar with the work of Sub-Committee 2 in the development of Freight Train Performance Charts as a means for showing the effect of new or improved facilities or the effect of increases or decreases in traffic upon freight train performance. Fig. 2 is one of these charts, which shows the changes that have taken place year after year since 1921 as the result of capital expenditure for new facilities or im-

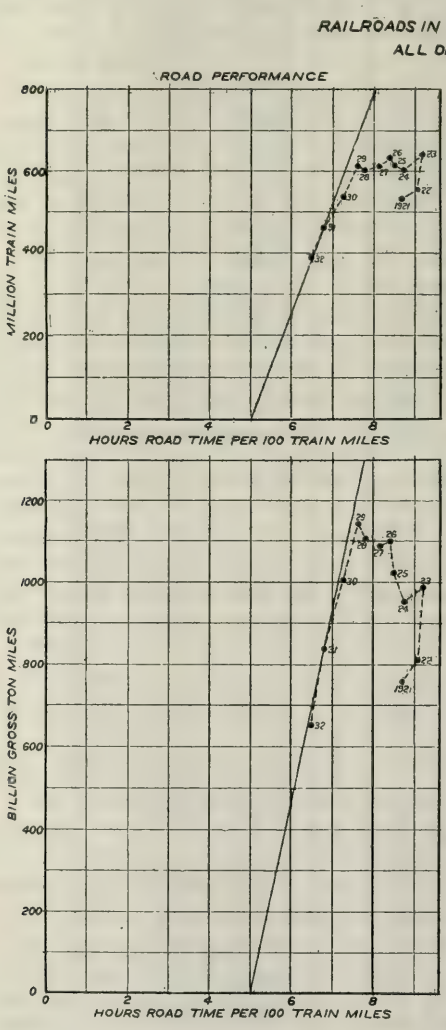


FIG. 2

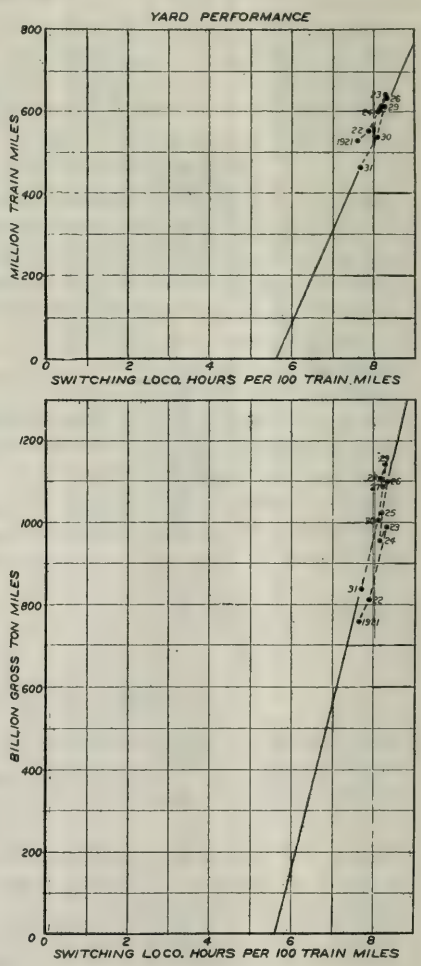


FIG. 3

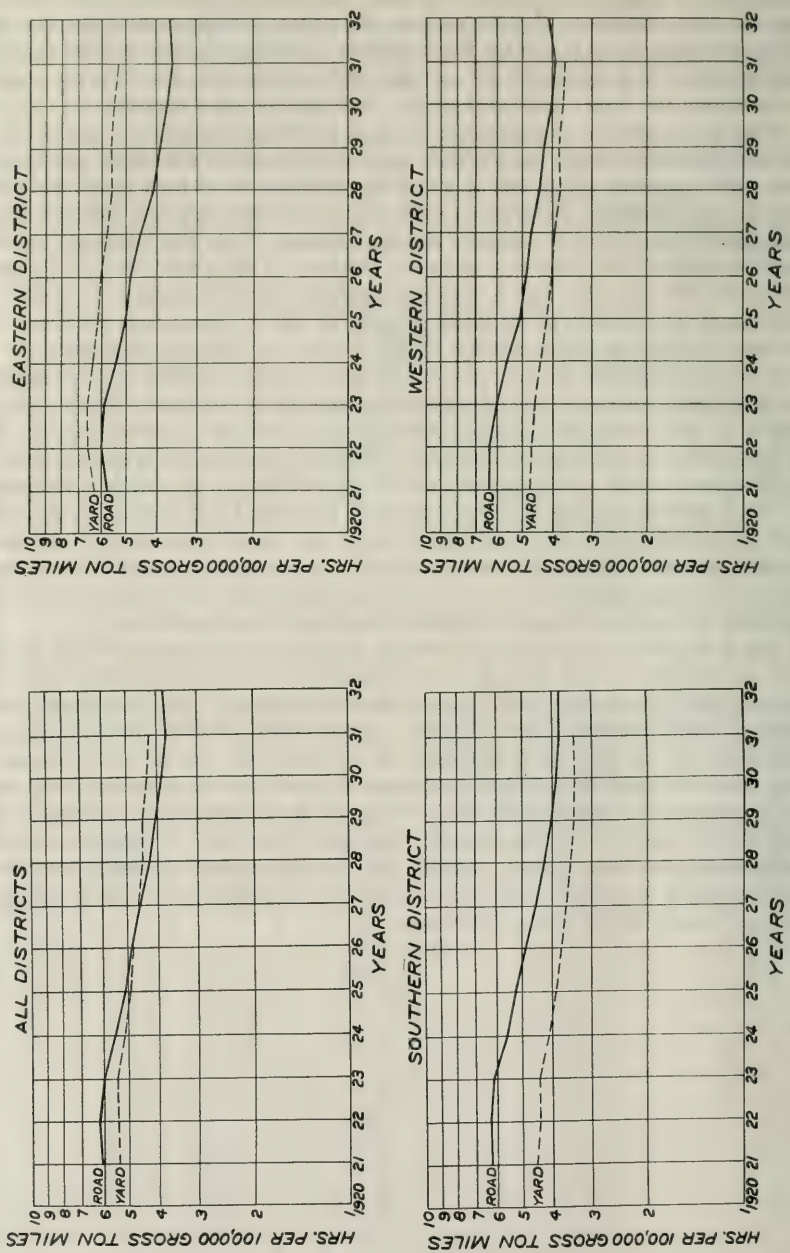
provements in operating methods. This chart also shows that Freight Train Performance has been maintained during the past three years notwithstanding all the efforts which have been made to combat the depression. During this latter period capital expenditures have been practically nil and the results obtained are exactly what would be expected from the theory developed several years ago by Sub-Committee 2.

Fig. 3 is a similar chart applied to yard switching performance and shows the switching locomotive hours per 100 train miles plotted against train miles and gross ton miles. By comparing Fig. 2 and 3, it will be seen that the changes which have taken place in yard switching performance since 1921 are small compared with the changes which have taken place in freight train performance. This may or may not be a natural condition. The point it is desired to bring out at this time is that yard performance varies with increases and decreases in traffic in the same manner as freight train performance, as indicated in the lower diagram of Fig. 3. Since train miles are not a measure of traffic, the upper diagram of Fig. 3 has practically no significance.

After a considerable study of statistics in order to find a suitable unit for measuring switching service the gross ton mile has been found to be the most practical. For the purpose of this discussion it seems unnecessary to adjust the reported gross ton miles for the increase in tare weight of freight cars and for the increase in average length of haul in order to have a truer measure of the duty performed by switching locomotives.

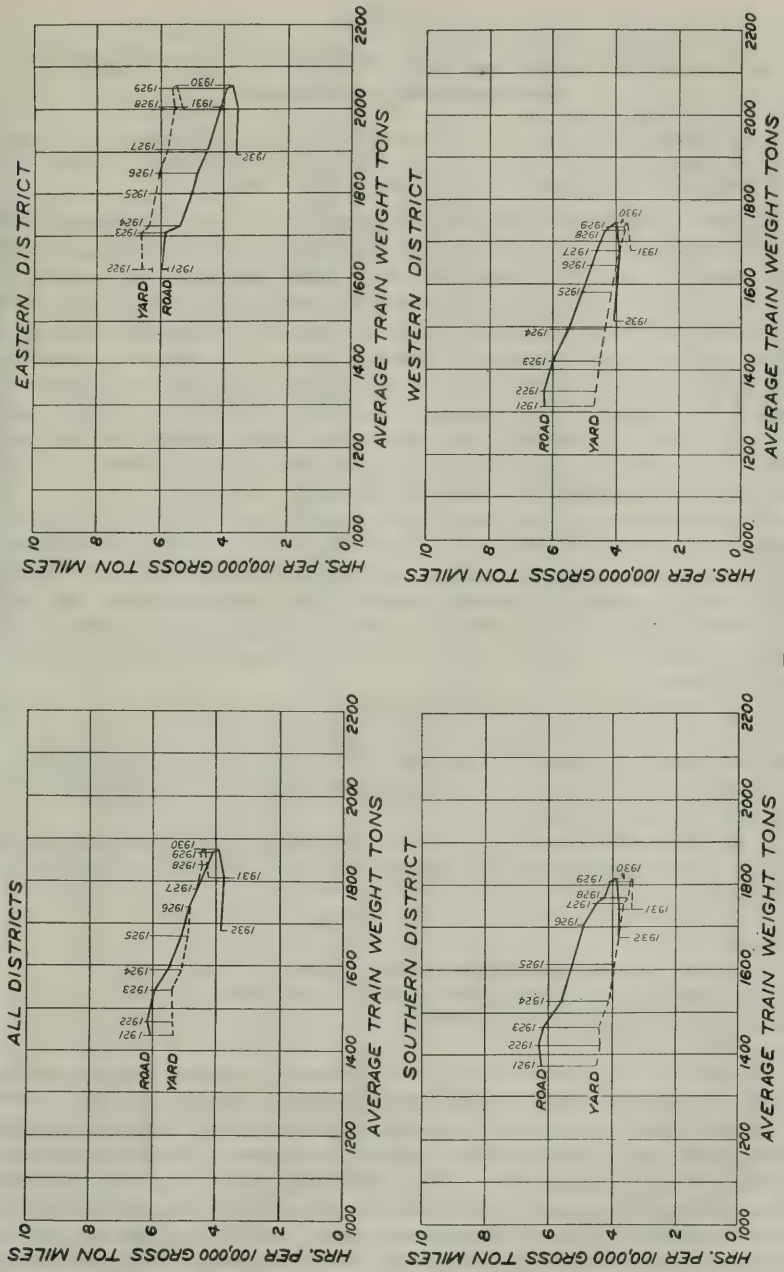
Fig. 4 gives a comparison of road time and switching locomotive hours per 100,000 gross ton miles by years and by districts to show the trends independent of the amount of traffic handled. In some ways it reflects the net results obtained from a general program of improvement from year to year. In individual cases it may be possible to go farther and analyze the results obtained from specific improvements.

Fig. 5 has been prepared for the purpose of indicating the progress which has been made in performance with respect to the operation of heavy trains. The hours road time per 100,000 gross ton miles have decreased between 1921 and 1930 as the average weight of trains increased. Since 1930 the average weight of trains has been decreasing while there has not been much change in the average road time per 100,000 gross ton miles, notwithstanding the fact that the amount of traffic has also decreased, which should tend to decrease the average road time. No doubt the present unusual economic conditions are the causes for the retrogressions which have taken place. If and when economic conditions improve data will be available for a more complete analysis from which it may be possible to determine the advantages or disadvantages of operating long heavy trains as regards yard switching performance.



Comparison Freight Train and Yard Switching Performance, by Years

Fig. 4



Comparison Freight Train and Yard Switching Performance Basis of Train Weight

Fig. 5

Appendix D

(6) EFFECT OF VOLUME OF TRAFFIC ON RAILWAY OPERATING EXPENSES

S. W. Fairweather, Chairman, Sub-Committee; Miss Olive W. Dennis, J. M. Farrin, G. W. Hand, E. M. Hastings, C. H. R. Howe, M. F. Mannion, J. F. Pringle, Mott Sawyer, M. F. Steinberger, C. C. Williams, John Worley.

Students of railway expense have long realized that there exists a relationship between operating expenses and traffic, which is not completely reflected by the operating ratio. Very little study is required to prove that, other things being equal, the operating ratio of a railway is some function of the traffic density. This conclusion has found expression in various attempts to divide railway expenses into two parts, one designated as the fixed expense, and the second designated as variable expense. The division of operating expenses under these two groups in the past has been largely left to a common-sense judgment of the various items of expense, as developed in the primary expense classification of the Interstate Commerce Commission. The "Yager Formula" of the American Railway Engineering Association is an example of this form of treatment, having particular reference to maintenance of way and structures expenses.

The determination of fixed and variable expenses on the basis of common-sense judgment is open to the criticism that it is merely a guess. It is therefore possibly desirable to see to what extent the problem lends itself to statistical analysis, and inasmuch as there does not appear to have been submitted to the Association as yet any example of a statistical analysis on the basis of rectilinear correlation by the method of least squares, occasion will be taken during the process of the analysis to develop briefly the underlying theory.

As a preliminary to the analysis, a judgment of the factors which are to be considered must be made. Operating expenses and traffic density have already been mentioned, but capital investment per mile as a third factor must also be considered. A failure to include the effect of increasing capital investment upon operating expenses might tend to vitiate the result.

If the operating expenses of a road are susceptible, with a reasonable degree of accuracy, of being expressed by the equation of a plane, the equation, in simple form, would be

$$z = C + Ax + By$$

Where

z = Operating expenses per mile of railway
x = Traffic per mile, or in other words, the density of traffic
y = Capital investment per mile
C = A constant

The analysis will attempt to define the values of these constants and coefficients. In order to reduce to a minimum accidental variations in the data, all Class I roads of the U.S. are treated as a unit and the expenses for 1900 to 1929 inclusive are analyzed. It is recognized that in approaching the problem in this manner the difficulties inherent in handling a time series are incurred. These difficulties, so far as they arise from changes in price levels and wages, may be approximately allowed for by the application of index numbers reducing the data to a common price basis. On the other hand, the time series enables the analysis to include the effect of capital investment, which could not otherwise be done. The basic data for the analysis, therefore, consists in a tabulation of the miles of road, the traffic, the investment in road and equipment, operating expenses and the index of wages and cost of material, all of which are given on page 911.

TABLE 1

Year	Mileage (Oper.)	Traffic (Millions)	Expense (Millions)	Mileage (Invest)	Investment (Millions)	Index 1913=100
1900	186,876	417,283	$ 961	181,437	$10,263	77.55
1901	189,956	415,866	1,030	182,734	10,405	80.10
1902	194,768	467,684	1,116	187,442	10,658	82.35
1903	199,411	508,741	1,258	193,823	10,974	83.65
1904	205,605	520,144	1,339	198,841	11,512	86.90
1905	209,405	555,766	1,391	203,228	11,951	84.15
1906	214,474	621,613	1,537	208,311	12,420	83.45
1907	219,129	677,091	1,749	210,792	13,030	86.40
1908	221,833	675,020	1,670	213,888	13,066	93.95
1909	226,006	693,214	1,599	221,679	13,451	87.65
1910	230,474	782,805	1,823	226,114	14,388	88.80
1911	207,307	788,066	1,844	223,844	15,185	92.00
1912	210,118	812,583	1,899	228,317	15,761	95.30
1913	213,959	896,530	2,109	223,891	16,320	100.00
1914	216,553	896,159	2,140	227,404	16,870	102.25
1915	219,013	873,739	2,021	230,016	17,235	104.95
1916	220,890	1,009,554	2,211	232,315	17,544	112.20
1917	222,246	1,102,950	2,829	233,517	18,423	133.95
1918	223,044	1,090,479	3,972	233,992	18,842	176.05
1919	224,362	1,028,603	4,378	235,156	19,168	187.10
1920	224,594	1,164,226	5,831	236,393	19,720	229.80
1921	223,957	948,557	4,563	234,960	20,215	213.70
1922	224,488	1,003,702	4,415	233,827	20,462	201.40
1923	224,763	1,185,746	4,895	233,060	21,258	201.75
1924	225,022	1,154,307	4,508	232,592	22,072	200.10
1925	225,660	1,238,046	4,537	232,507	22,630	200.30
1926	225,683	1,330,146	4,669	229,938	22,942	200.80
1927	227,230	1,291,635	4,574	228,582	23,430	200.80
1928	229,088	1,307,800	4,428	228,404	23,763	200.45
1929	230,280	1,335,703	4,506	228,115	24,314	204.15

These figures are based upon the Interstate Commerce Commission's statistics, but, of necessity, adjustments have been made in order to obtain reasonably comparable figures throughout the period. The traffic in millions of gross ton miles has been computed using the reported revenue ton miles (freight figures), the freight car miles and the passenger car miles, the average weight of freight cars and of passenger cars being applied to these figures. It may be interesting to note that the average weight of freight cars in the period increased from 14.9 tons in 1900 to 21.2 tons in 1929 and the average weight of passenger cars from 38.7 tons to 55.1 tons.

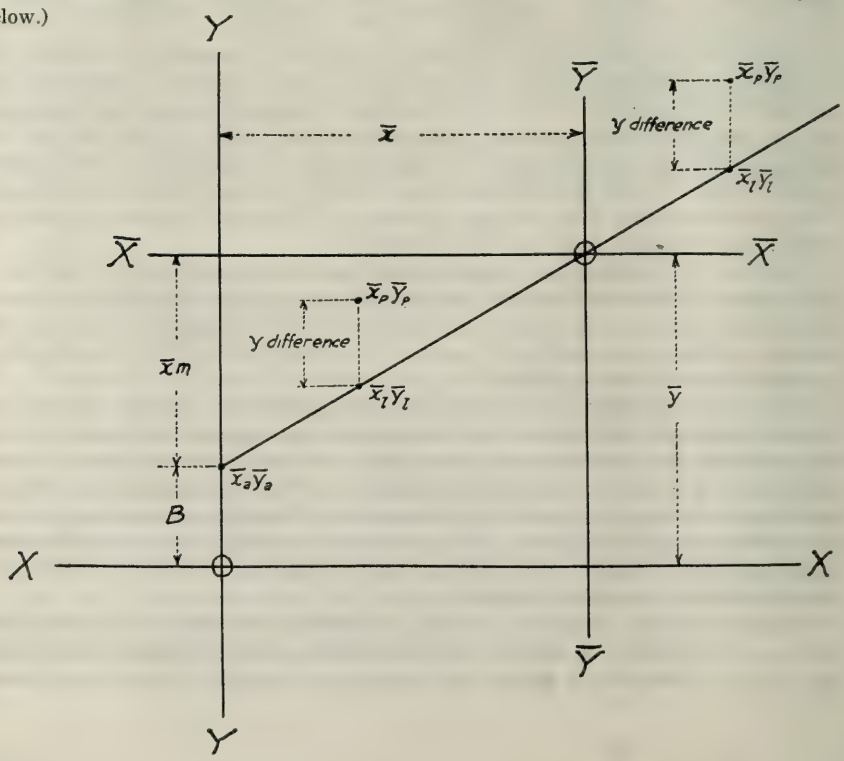
Prior to 1911 no distinction is made between Class I and Class II roads in the Interstate Commerce Commission statistics, and therefore up to and including 1910 the operating statistics relate to both Class I and Class II roads. Subsequent to that date the operating statistics relate to Class I roads. The mileage operated has been corrected for the elimination of trackage rights.

The investment figures and the mileage applicable thereto include Class I and Class II roads and their non-operating subsidiaries, and represent investment in road and equipment and improvements in leased lines. The figures are recognized as being approximate on account of the lack of continuity of strictly comparable data, but are nevertheless believed to be reasonably representative. The index relating costs to 1913 as a base is a composite of railway labour and railway material. In computing this index wages were given a weight of 65, iron and steel a weight of 5, timber a weight of 5 and miscellaneous materials a weight of 25.

Further treatment of the data requires a theoretical consideration of the theory of rectilinear correlation. For simplicity, consider the case of two variables y and x, such that $y = f(x)$. Since we are dealing with rectilinear correlation $f(x)$ must be considered

as a straight line of the general equation $y = mx + B$. The analysis, therefore, becomes a problem of determining the value of m the slope of the line, and B the intercept of the line on the Y axis. The application of the analysis will usually be to data representing many particular cases of y in relation to x. For instance, there will be many particular cases of investment per mile in relation to traffic density per mile. If the data be plotted on rectangular coordinates, the various points, instead of lying smoothly along a straight line, will be found to be scattered somewhat, although by visual inspection it is apparent that a trend or tendency to a straight line exists. Quite obviously, this trend line must pass through the arithmetic mean of the x and y values, or to put it in another way, the average line must pass through the center of gravity of the points; but when we come to the question as to what the slope of the line should be, or indeed whether we are justified in drawing a conclusion that a straight line does reasonably satisfy the points in question, we are driven to a consideration of the law of probabilities. According to the law of probabilities, the most probable value of a series of observations is that value which will make the sum of the squares of the differences between it and the observed values a minimum. This value is the arithmetic mean of the data and is the reason why the center of gravity of all the points must lie on the mean line. Similarly, the most probable mean line is defined as the one with regard to which the sum of the squares of the distances of the observed points from the mean line is at a minimum. It is from this characteristic that the term "Method of Least Squares" is derived. It should be noted that, generally speaking, the slope of the mean line will differ depending upon whether the line is fitted to produce the minimum squares of the y differences or the minimum squares of the x differences.

Since the relation to be discovered is the most probable value of y in relation to variations of x, the trend line will be fitted in such a manner as to produce the minimum sum of the squares of the y differences. To fit the line to the points, let a subsidiary set of co-ordinates be passed through the center of gravity of the points. (See diagram below.)



The value of the y difference on the new set of co-ordinates between any given point and a point on the desired trend line having the same x value is

$$y \text{ difference} = \bar{y}_p - \frac{\bar{x}_p \bar{y}_a}{\bar{x}}$$

Where $\bar{y}_p$ and $\bar{x}_p$ are the co-ordinates of the point referred to the new axis, $\bar{y}_a$ is the $\bar{y}$ value of the intercept between the new $\bar{X}\bar{X}$ axis and the trial line on the YY axis, and $\bar{x}$ is the x value of the new axis. The sum of the squares of the differences is therefore:

$$\Sigma\,(y \text{ differences})^2 = \Sigma(\bar{y}_p^2) - \Sigma\left(\frac{2\bar{y}_p\,\bar{x}_p}{\bar{x}}\,\bar{y}_a\right) + \Sigma\left(\frac{\bar{x}_p^2\,\bar{y}_a^2}{\bar{x}}\right)$$

Differentiating $\Sigma(y \text{ differences})^2$ with regard to $\bar{y}_a$ and equating to zero to obtain a minimum value of the squares of the y differences, we obtain:

$$\frac{2\bar{y}_a}{\bar{x}^2}\,\Sigma\,(\bar{x}_p^2) - \frac{2}{\bar{x}}\,\Sigma(\bar{y}_p\bar{x}_p) = O$$

$$\text{whence } \frac{\bar{y}_a}{\bar{x}} = \frac{\Sigma(\bar{y}_p\,\bar{x}_p)}{\Sigma(\bar{x}_p^2)}$$

$\frac{\bar{y}_a{}^2}{\bar{x}}$ is the slope of the most probable trial line and the intercept of this line on the Y axis is $\bar{y} - y_a$. The values of m and of B in the basic equation therefore have been determined in such a manner as to satisfy the law of least squares and therefore the law of probabilities. Assuming a normal frequency distribution of the points about the mean line, which is a reasonable assumption where there is a large number of points, it is possible to deduce certain relationships which test the reasonableness of the basic assumption that y is a rectilinear function of x. The square root of the sum of the squares of the differences furnishes a test of the probable error. It is analogous to the radius of gyration in mechanics. The probable error, assuming a normal frequency distribution, is equal to $.67\sqrt{\frac{\Sigma(y \text{ differences})^2}{N}}$, N being the number of points. It simply means that any particular value of y has an equal chance of being nearer to the mean value than further away from it. In other words, 50 per cent of all the y values will be no further away than this amount from the mean.

For instance, the probable error of a horizontal line through the mean of the x and y values may be tested by this formula, the y difference in this case being the $\bar{y}$ co-ordinates of the points; likewise, the probable error of the line fitted by the method of least squares may be determined, in this case, the y difference being the differences between the $\bar{y}$ co-ordinates of the points and the $\bar{y}$ co-ordinates of points on the line having the same x value. If it is found that the probable error with regard to the line fitted by the method of least squares is smaller than the probable error of a horizontal line, it shows that we have improved the accuracy of the fit by rotating the line to the value where $m = \Sigma\frac{\bar{x}\bar{y}}{\bar{x}^2}$. Likewise, a comparison of the reduction in the probable error affords some measure of the reasonableness of the fit.

This relationship between these two probabilities has been expressed in terms of what is called the correlation factor, which is an absolute numerical expression of the

degree to which y may be said to vary with x, taking into account the dispersion of the points. The correlation factor of which the standard symbol is r is equal to

$$\sqrt{1-\frac{(\text{the probable error of the fitted line})^2}{(\text{the probable error of a horizontal line})^2}}$$

From this equation it is apparent that all values of the coefficients of correlation must lie between 0 and 1. If the value is 1, it means that all the points fall accurately on the line in question; if the value is 0, it means either that the dispersion is so great that any line fits the data as well as any other line, or that the points fall accurately on a line parallel to the x axis, in which latter case of course y would not vary with x. For reasonably accurate treatment of the statistical data by rectilinear correlation, the value of r should be reasonably high. Values above .9 are quite satisfactory.

There are statistical short cuts for the determination of m and B, as well as for the determination of the probable error and of the coefficient of correlation, which may be obtained from any modern work on statistical methods.

Inasmuch as the problem at hand is to develop the relation between operating expenses and traffic density and investment in road and equipment, it will be necessary to deal with three-dimensional co-ordinates and the data must be considered as points in space referred to three planes mutually at right angles. It will be convenient to consider the horizontal or XY plane as representing relationship between traffic density and unit investment in road and equipment, and the ZX plane and the ZY plane as representing the relationship between unit operating expenses z, traffic density x, and unit investment in road and equipment y. The x, y and z values representing the conditions for all Class I roads 1900–1929 are as follows:

Table 2

Year	*x* *Traffic Density*	*y* *Unit Investment*	*z* *Unit Expense*
1900	2,233	$ 72,940	$ 6,630
1901	2,189	73,391	6,770
1902	2,401	73,185	6,962
1903	2,551	72,726	7,542
1904	2,530	74,004	7,495
1905	2,654	74,975	7,894
1906	2,898	75,843	8,588
1907	3,090	78,300	9,237
1908	3,043	77,344	8,015
1909	3,067	76,606	8,071
1910	3,397	79,769	8,908
1911	3,801	84,447	9,667
1912	3,867	85,438	9,485
1913	4,190	89,624	9,857
1914	4,138	90,605	9,665
1915	3,989	91,089	8,794
1916	4,570	91,415	8,923
1917	4,963	93,800	9,503
1918	4,889	95,055	10,115
1919	4,585	95,324	10,430
1920	5,184	95,840	11,296
1921	4,235	97,412	9,533
1922	4,471	98,410	9,764
1923	5,276	100,429	10,794
1924	5,130	102,381	10,012
1925	5,486	103,618	10,037
1926	5,894	105,450	10,302
1927	5,684	107,139	10,025
1928	5,709	107,949	9,643
1929	5,800	109,269	9,584

x—Thousands of Gross Ton Miles per Mile.
y—Adjusted Investment per Mile = Investment as of 1900 divided by price-wage index for 1900, plus total, to date, of increases for each subsequent year divided by price-wage index of corresponding year.
z—Adjusted Operating Expense per Mile = Actual Expense divided by price-wage index.

By the method outlined above, the most probable plane which can be passed through the mean value of the points and be perpendicular to the ZX plane, may be determined, detail calculation being as follows:

z = Unit Expense in Thousands of Dollars per Mile.
x = Traffic Density in Millions of G.T.M. per Mile.
N = Number of cases (years) considered.

$$\bar{x} = x - \frac{\Sigma(x)}{N} \qquad \bar{z} = z - \frac{\Sigma(z)}{N}$$

$$m = \frac{\Sigma(\bar{x}\bar{z})}{\Sigma(\bar{x}^2)}$$

$$d = \bar{z} - m\bar{x}$$

TABLE 3

Year	z	x	$\bar{z}$	$\bar{x}$	$\bar{x}\bar{z}$
1900	6.630	2.233	2.488	1.831	4.556
1901	6.770	2.189	2.348	1.875	4.403
1902	6.962	2.401	2.156	1.663	3.585
1903	7.542	2.551	1.576	1.513	2.384
1904	7.495	2.530	1.623	1.534	2.490
1905	7.894	2.654	1.224	1.410	1.726
1906	8.588	2.898	.530	1.166	.618
1907	9.237	3.090	.119	.974	.116
1908	8.015	3.043	1.103	1.021	1.126
1909	8.071	3.067	1.047	.997	1.044
1910	8.908	3.397	.210	.667	.140
1911	9.667	3.801	.549	.263	.144
1912	9.485	3.867	.367	.197	.072
1913	9.857	4.190	.739	.126	.093
1914	9.665	4.138	.547	.074	.040
1915	8.794	3.989	.324	.075	.024
1916	8.923	4.570	.195	.506	.099
1917	9.503	4.963	.385	.899	.346
1918	10.115	4.889	.997	.825	.823
1919	10.430	4.585	1.312	.521	.684
1920	11.296	5.184	2.178	1.120	2.439
1921	9.533	4.235	.415	.171	.071
1922	9.764	4.471	.646	.407	.263
1923	10.794	5.276	1.676	1.212	2.031
1924	10.012	5.130	.894	1.066	.953
1925	10.037	5.486	.919	1.422	1.307
1926	10.302	5.894	1.184	1.830	2.167
1927	10.025	5.684	.907	1.620	1.469
1928	9.643	5.709	.525	1.645	.864
1929	9.584	5.800	.466	1.736	.809
Total	273.541	121.914			36.023
Mean	9.118	4.064			1.201

TABLE 3 (Continued)

Year	$\bar{x}^2$	$m\bar{x}$	d	d^2	$\bar{z}^2$
1900	3.353	1.610	.878	.771	6.190
1901	3.516	1.648	.700	.490	5.513
1902	2.766	1.462	.694	.482	4.648
1903	2.289	1.330	.246	.061	2.439
1904	2.353	1.349	.274	.075	2.634
1905	1.988	1.240	.016	.000	1.498
1906	1.360	1.025	.495	.245	.281
1907	.949	.856	.975	.951	.014
1908	1.042	.898	.205	.042	1.217
1909	.994	.876	.171	.029	1.096
1910	.445	.586	.376	.141	.044
1911	.069	.231	.780	.608	.301
1912	.039	.173	.540	.292	.135
1913	.016	.111	.628	.394	.546
1914	.005	.065	.482	.232	.299
1915	.006	.066	.258	.067	.105
1916	.256	.445	.640	.410	.038
1917	.808	.790	.405	.164	.148
1918	.681	.725	.272	.074	.994
1919	.271	.458	.854	.729	1.721
1920	1.254	.985	1.193	1.423	4.744
1921	.029	.150	.265	.070	.172
1922	.166	.358	.288	.083	.417
1923	1.469	1.065	.611	.373	2.809
1924	1.136	.937	.043	.002	.799
1925	2.022	1.250	.331	.110	.845
1926	3.349	1.609	.425	.181	1.402
1927	2.624	1.424	.517	.267	.823
1928	2.706	1.446	.921	.848	.276
1929	3.014	1.526	1.060	1.124	.217
Total	40.975			10.738	42.366
Mean	1.366			.358	1.412

The equation of this plane is $z = .879 + 5.545$

The probable z error with regard to this plane is .404 as compared with the probable z error of .801 with regard to a horizontal plane through the mean value or centre of gravity of the points. The correlation factor is reasonably high, being .864. Therefore the plane $z = .879 + 5.545$ fits the points reasonably well. Similarly, the most probable plane passing through the mean of the z values perpendicular to the ZY axis may be determined. By calculation similar to the above, it develops $z = .801\,y + 1.976$. The probable error of the z values with regard to this plane is .467. The probable error with regard to a horizontal plane remains as before .801 and again the plane is seen to fit the points reasonably well, the correlation factor being .813. The intersection of these two planes defines a straight line in space, the graphical representation of which is shown upon Graphs, Diagrams 1, 2 and 3.

This line of course passes through the mean of the x, y and z values, which is

$x =$ Traffic density $= 4.064$
$y =$ Investment per mile $= 8.913$
$z =$ Operating expenses per mile $= 9.118$
x being measured in millions of equivalent gross ton miles,
y in tens of thousands of dollars equated to 1913 value, and
z in thousands of dollars equated to 1913 value.

The average line punctures the ZY plane at a y value of 4.453, with a z value of 5.545, the value of x being 0. This might be interpreted as meaning that the investment

in a road equipped to do business but as yet having no business, would be $44,530 (equated) per mile and the operating expenses would be $5,545 per mile, being of course all fixed.

The next step is to determine whether there is any particular plane which can be passed through this line which will fit the data in such a manner as to produce a still lower probable error of the z values than the planes which were passed at right angles to the ZX and ZY planes. To test this a reference plane may be passed through the line in such a manner that lines in the plane at right angles to the average line are parallel to the XY plane. The equation of this plane is $z = 3.60 + .399\,x + .437\,y$. z differences between the points and this plane may then be determined and the degree to which the plane should be rotated to produce a minimum sum of the squares of the z differences can be investigated.

By a process similar to that which has already been developed, it may be shown that the tilt of the plane normal to the axis, to produce the minimum sum of the squares of the distances between the points and the tilted plane is determined by the ratio $\frac{\Sigma(\delta z \times h)}{\Sigma(h^2)} \times \cos\phi$ where δz is the vertical distance between any point and the plane, h is the perpendicular distance measured in the XY plane between the trace of the point and the trace of the axis, and $\cos\phi$ is the cosine of the angle made between the axis and the XY plane. For convenience, the degree of dispersion about the axis may be plotted to oblique co-ordinates. In this projection the axis will appear as a point, the reference plane will appear as a horizontal line, and δz will appear as ordinates above or below the horizontal line. The planes which have previously been investigated, one at right angles to the ZX plane, and the other at right angles to the ZY plane, are shown on the graph, Diagram No. 4, as well as the plane which produces the minimum $\Sigma(\delta z^2)$. The equation of this plane related to the original axis of co-ordinates is $z = 8.05 + 1.496\,x - 0.562\,y$. The probable z error of this plane is .388 as compared with a probable error of the data at large of .801, and the correlation factor is .877.

In using this formula, it must be borne in mind that it is only applicable to cases where the x and y values, i.e. the traffic density and the investment per mile, approximately satisfy the equation $y = 1.097\,x + 4.453$. If an attempt is made to apply the formula to values of x and y very far from this condition, the data would be forced to an unwarranted extent. Keeping in mind this limitation, it will be seen that the equation confirms the general experience that operating expenses are decreased by an increase in investment, the equation showing that an increase of $10,000 per mile in capital expenditures would produce a decrease in operating expenses of $560 per mile. It is interesting to compare this result with the average interest rate of say 5½ per cent which would add $550 to the fixed charges, but it must be kept in mind that in addition to enabling the reduction in operating expenses to take place, the additional investment also increases the capacity of the property.

From these equations it is possible to determine the percentages of operating expenses which are fixed and variable at a given traffic density, certain qualifications being taken into account. The first of these is that the determination applies to an increase in traffic density and not to a decrease. The second is that it applies to normal average conditions, the third that it implies increasing investment at the amount of $10,970 per million equated gross ton miles. The equation for operating expenses under these assumptions is $z = .879\,x + 5.545$. The increment in expense per million equivalent gross ton miles is .879 ($879) per mile of road. z may be divided into z_f, z_v; z_f being the fixed expense and z_v the variable expense. Since we are dealing with a straight line, z_f

is B and z_v is mx in the general equation $z = mx + B$. The percentage of expense which is proportional to increased traffic at any traffic density x is therefore $\frac{mx}{mx + B}$. For various traffic densities and for the stated average investment per mile of line, the proportion of expenses which is variable is therefore as follows:

TABLE 4

Traffic Density (Millions)	*Normal Investment per mile*	*Per Cent Expense Variable with Traffic*	*Per Cent Expense Fixed*
2	$ 66,500	24.1	75.9
3	77,500	32.2	67.8
4	88,500	38.8	61.2
5	99,000	44.2	55.8
6	110,000	48.7	51.3
7	121,000	52.6	47.4

A final word of caution might be added. It must not be inferred that the result is applicable to sudden changes in traffic density, either increases or decreases. What has been accomplished is to give statistical expression to the historical development of U.S. Roads for the 30 years between 1900 and 1929 in relation to increasing traffic density and increasing investment in property. The method which has been used is applicable to many cases of statistical analysis and has the merit that it avoids the perils connected with the forcing of data to yield conclusions which cannot be supported.

As a practical application of the analysis, let it be supposed that a railway with traffic density 6,000,000 gross ton miles per mile with approximately the normal capital relationship had an operating ratio of .75, what might be the effect of a 10 per cent increase in traffic on the operating ratio?

By reference to Table 4 it will be seen that on such a road 51.3 per cent of the expenses are fixed and 48.7 per cent are variable. The operating ratio under the new conditions would therefore be:

$$\frac{.75}{1.10}\left\{.513 + (1.10 \times .487)\right\}$$

This equals .715 so that the increase of 10 per cent in traffic under these conditions would produce a decrease in the operating ratio of .035.

Another application follows: A road with a traffic density of 6,000,000 gross ton miles per mile and with an operating ratio of .75, having experienced up to that time the average trend of capital expenditures decides to put no additional capital into the property; an increase in traffic of 10 per cent occurs—what would the operating ratio be?

Referring to Table 4, and substituting 6.0 for the value of x (traffic density in million gross ton miles), and 11.0 for the value of y (investment per mile of road in tens of thousands of dollars), in the basic equation $z = 8.05 + 1.496x - 0.562y$, as developed on page 917, the value of z (operating expenses per mile) may be determined in units of one thousand dollars. Solving this equation, $z = 8.05 + 1.496 \times 6.0 - 0.562 \times 11.0$. $z = 10.844$, or $10,844.

With a 10 per cent increase in traffic and no increase in investment, the equation becomes $z = 8.05 + 1.496 \times 1.10 \times 6.0 - 0.562 \times 11.0$. $z = 11.741$, or $11,741.

The corresponding operating revenue per mile with an operating ratio of 0.75 is equivalent to $10,844 ÷ 0.75, or $14,459. With a 10 per cent increase in traffic, the corresponding operating revenue is equivalent to 14,459 × 1.10, or $15,905 per mile. The operating ratio with a 10 per cent increase in traffic, therefore, would be 11,741 ÷ 15,905, or 0.738.

Diagram 1.

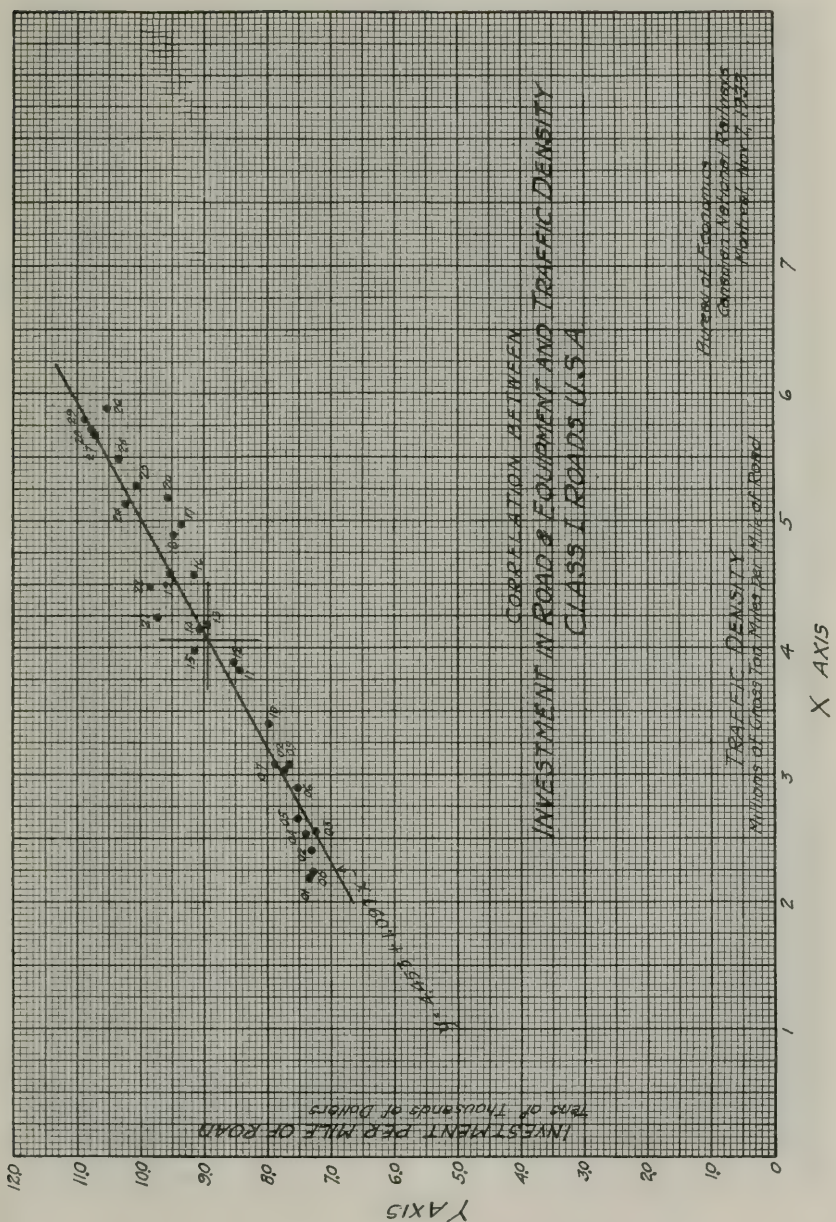

CORRELATION BETWEEN
INVESTMENT IN ROAD & EQUIPMENT AND TRAFFIC DENSITY
CLASS I ROADS U.S.A.
Bureau of Economics
Canadian National Railways
Montreal, Nov. 1, 1933
TRAFFIC DENSITY
Millions of Gross Ton Miles per Mile of Road
INVESTMENT PER MILE OF ROAD
Tens of Thousands of Dollars
X AXIS
Y AXIS

Diagram 2.

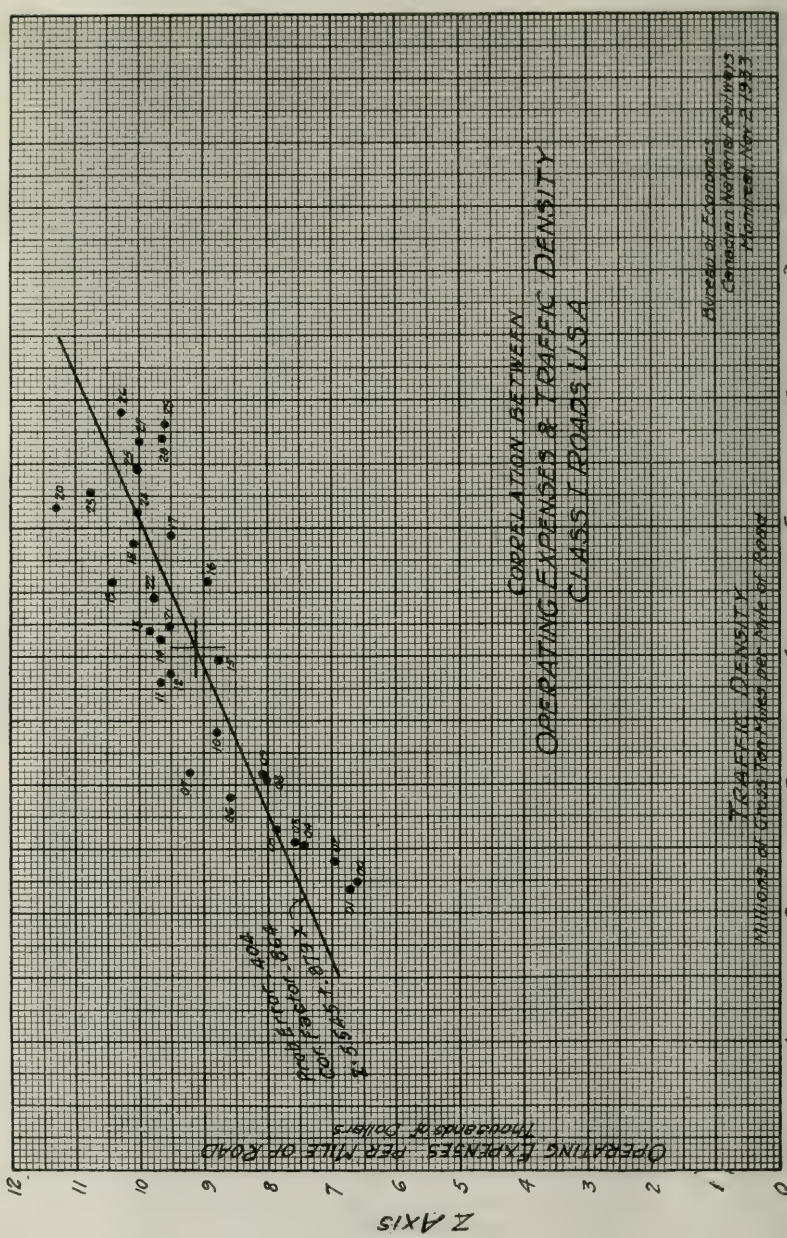

CORRELATION BETWEEN
OPERATING EXPENSES & TRAFFIC DENSITY
CLASS I ROADS U.S.A.
Bureau of Economics
Canadian National Railways
Montreal, Nov 2 1933
TRAFFIC DENSITY
Millions of Gross Ton Miles per Mile of Road
X AXIS
Z AXIS
OPERATING EXPENSES PER MILE OF ROAD
Thousands of Dollars
Prob. Error .404
Cor. Factor .864
Σ 5.545 + .873 X

Diagram 3.

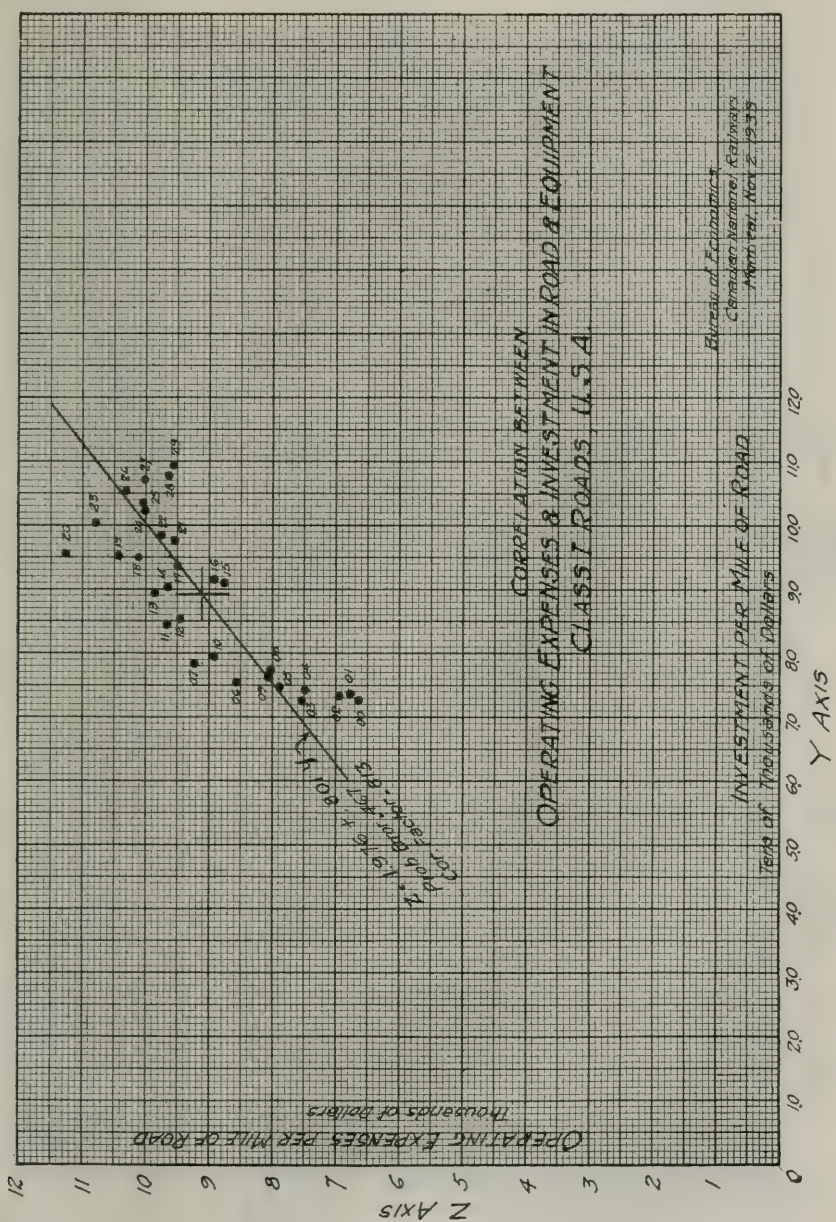
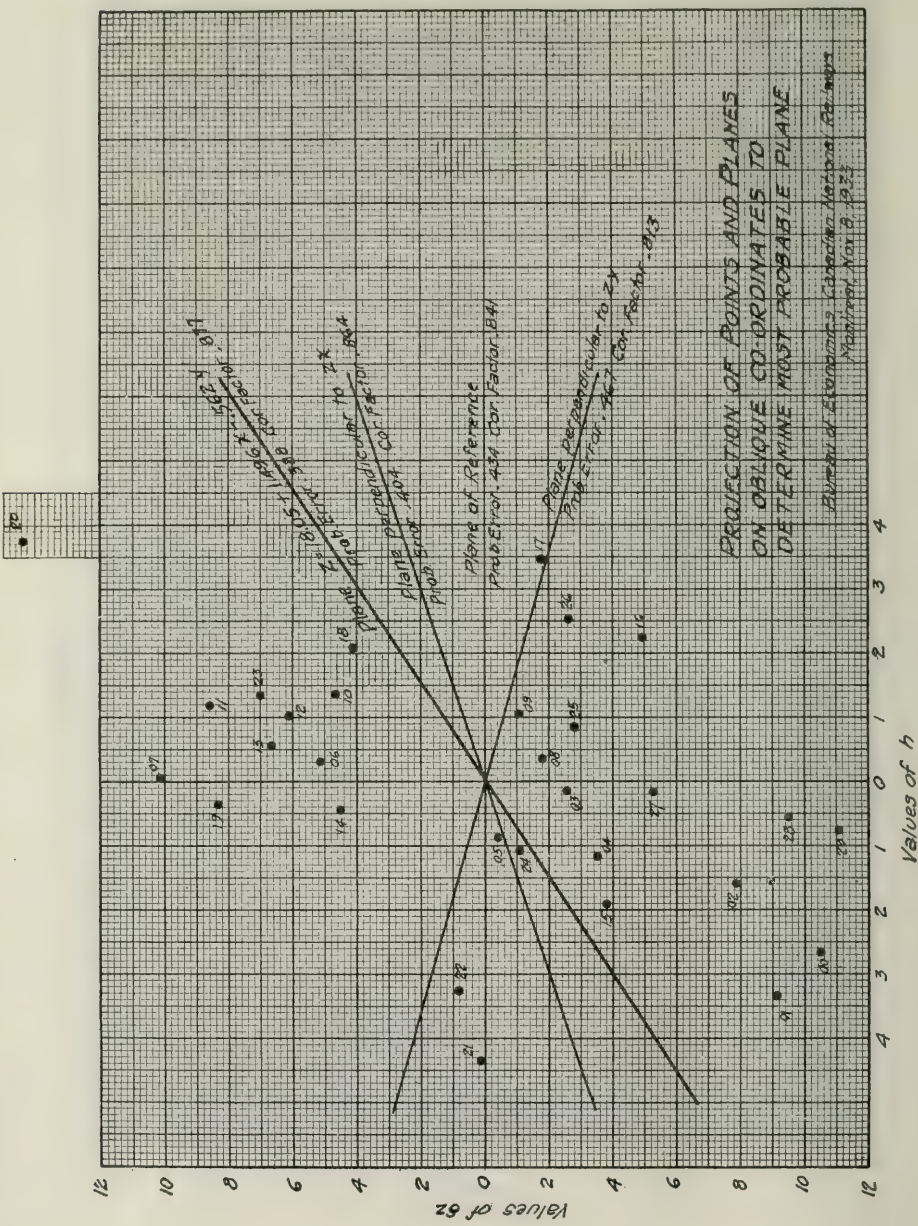

CORRELATION BETWEEN
OPERATING EXPENSES & INVESTMENT IN ROAD & EQUIPMENT
CLASS I ROADS, U.S.A.
Bureau of Economics
Canadian National Railways
Montreal, Nov 2, 1939
INVESTMENT PER MILE OF ROAD
Tens of Thousands of Dollars
Y AXIS
OPERATING EXPENSES PER MILE OF ROAD
Thousands of Dollars
Z AXIS

Diagram 4.


PROJECTION OF POINTS AND PLANES
ON OBLIQUE CO-ORDINATES TO
DETERMINE MOST PROBABLE PLANE
Plane of Reference
Prob. Error .434 Cor. Factor .841
Plane perpendicular to Zx
Prob. Error .467 Cor. Factor .813
Values of h
Values of 6z

REPORT OF COMMITTEE V—TRACK

C. J. Geyer, *Chairman;*
C. A. Alden,
W. H. Bettis,
W. H. B. Bevan,
L. H. Bond,
M. D. Bowen,
R. W. E. Bowler,
C. W. Breed,
W. G. Brown,
E. W. Caruthers,
H. R. Clarke,
J. E. Deckert,
J. W. DeMoyer,
L. W. DesLauriers,
J. J. Desmond,
J. A. Ellis,
F. W. Gardiner,
F. S. Hales,
C. R. Harding,
W. J. Harris,
O. F. Harting,
F. W. Hillman,
J. E. Hogan,
E. T. Howson,
W. G. Hulbert,
T. T. Irving,
F. J. Jerome,
A. A. Johnson,
H. D. Knecht,
J. de N. Macomb,
F. H. Masters,
C. M. McVay,
J. C. Mock,
W. A. Murray,
J. B. Myers,
J. V. Neubert,
G. A. Peabody,
O. C. Rehfuss,
C. J. Rist,
W. L. Roller,
W. G. Arn, *Vice-Chairman*;
E. M. T. Ryder,
J. R. Scatterday,
I. H. Schram,
G. L. Sitton,
G. J. Slibeck,
G. L. G. Smith,
Theo. Speiden, Jr.,
H. C. Stiff,
G. M. Strachan,
C. R. Strattman,
J. B. Strong,
E. D. Swift,
T. P. Warren,
J. R. Watt,
H. N. West,
J. G. Wishart,
M. J. T. Zeeman,

Committee.

To the American Railway Engineering Association:

Your Committee respectfully presents reports on the subjects assigned, as follows:

(1) Revision of Manual (Appendix A).

(1–A) Specifications for soft steel track spikes (Appendix B).

(2) String lining of curves by the chord method, and preparation of tables suitable for the use of trackmen (Appendix C).

(3) Plans and specifications for track tools, collaborating with Committees I—Roadway, II—Ballast, and XXII—Economics of Railway Labor (Appendix D).

(4) Plans for switches, frogs, crossings, slip switches, etc. (Appendix E).

(5) Track construction in paved streets, collaborating with Committee IX—Grade Crossings (Appendix F).

(6) Corrosion of rail and fastenings in tunnels. collaborating with Committee IV—Rail (Appendix G).

(7) Gage of track and elevation of curves with reference to the use of roller bearings on railway equipment, collaborating with the Mechanical Division of the A.R.A. (Appendix H).

(8) Effect of existing materials in track on the design of tie plates and punching thereof, together with the interrelation of slotting of joint bars and size of track spikes, collaborating with Committee IV—Rail (Appendix I).

(8-a) Design of tie plates for RE Rail Sections (Appendix I–1).

(9) Practicability of using "Reflex" units for switch lamps and targets, collaborating with Committee X—Signals and Interlocking (Appendix J).

(10) Selective welding up at joints, instead of welding out of face (Appendix K).

(11) Desirable tightness of track joints and effect upon the life of rails and joints of overtight joints; of loose joints (Appendix L).

(12) Reclamation of serviceable materials from scrap and retired maintenance of way and structure machines, tools and appliances, collaborating with Division VI—Purchases and Stores, A.R.A. (Appendix M).

(13) Methods of reconditioning of rail ends, fastenings, frogs and switches in track (Appendix N).

(14) Determination of the limiting relative positions of the abutting rails of fixed and drawspans on bridges and proper tolerances, collaborating with Committee X—Signals and Interlocking, XV—Iron and Steel Structures, and with Signal Section (Appendix O).

(15) Damage to track and devices due to brine drippings from refrigerator cars, collaborating with Mechanical Division, A.R.A. (Appendix P).

Action Recommended

(1) That revisions recommended in Appendix A be approved for publication in the Manual.

(2) That additions to the specifications for soft steel cut track spikes and malleable iron tie plates in Appendix B be adopted as recommended practice and published in the Manual, and that plans for 9/16 in. and 5/8 in. raised throat cut track spikes be received as information.

(3) That plans A, B, C–1, C–2, D–1, D–2, D–3, E, F, 21 and 22 in Appendix D be adopted as recommended practice and published in the Manual, and that plan 31, with study plans A and B, be received as information.

(4) That plan 505 in Appendix E be adopted as recommended practice and published in the Manual.

(5) That plans, Fig. 1 to 8, inclusive, in Appendix I be adopted as recommended practice and published in the Manual.

(6) That report in Appendix F be received as information.

(7) That report in Appendix H be received as information and the subject discontinued.

(8) That report in Appendix J be received as information.

(9) That report in Appendix K be received as information and the subject discontinued.

(10) That report in Appendix L be received as information and the subject discontinued.

(11) That report in Appendix N be received as information.

(12) That report in Appendix P be received as information and the subject discontinued.

(13) That progress reports in Appendices C, G, M and O be received as information.

Respectfully submitted,

The Committee on Track,

C. J. Geyer, *Chairman.*

Appendix A

(1) REVISION OF MANUAL

C. J. Geyer, Chairman, Sub-Committee; W. G. Arn.

The Committee recommends:

That the material shown under the headings "Table of Dimensions for Tie Plates" and "Data for Designing Tie Plates", on page 251 of the 1929 Manual, be withdrawn.

The Committee proposes as recommended practice, that the design of cut track spikes, appearing in the Manual at page 254, be revised as follows:

The elimination of the dimensions which provide for optional lengths of spikes and in substitution therefor incorporation of dimensions providing for a single length of 5½ in. between the throat and point for 9/16 in. spikes, and a single length of 6 in. for ⅝ in. spikes.

The Committee also recommends the withdrawal of track tool plans Nos. 1, 2, 3, 5, 6, 9, 11, 12, 13, 14, 15, 16, 18, and 19 adopted in 1930 and substitution of plans of like numberings herewith submitted.

The Committee deemed it advisable to review the plans, hereto approved, that now appear in the Book of Trackwork Plans, with the result that practically all of them have been revised. The principal revisions consist of:

Withdrawing Plans Nos. 271 to 279 inclusive, 281 to 283 inclusive, 291 and 292 and substituting therefor a new series of plans bearing the same numbers. The original plans show frogs for heavier rails up to 150 lb. per yard; at the present time the railroads are generally considering only rails weighing not more than 131 lb. per yard, consequently the new series of plans show frogs of considerably shorter lengths.

The March, 1933, Index Supplement, pages 4, 5, and 6, of the Book of Trackwork Plans describes a large number of approved revisions; these revisions have been made on the plans now being submitted, and this Index Supplement is now being withdrawn.

The Specifications for Switches, Frogs, Crossings and Guard Rails contained in Appendix B of the book of Trackwork Plans have been revised and enlarged to include pertinent data from the Specifications for Special Trackwork Materials, approved by the American Standards Association under its No. E10–1929.

In addition to the above, numerous other revisions of a minor character have been made on the plans for the sake of consistency and to bring them up to date.

Copies of the revised Book of Trackwork Plans with new Index will be available in the office of Secretary E. H. Fritch, after February 1, 1934, for examination.

The Committee recommends that the revisions outlined above be approved.

The Committee recommends the revision of Plans 780, 781 and 980, dated November, 1926, adopted March, 1927, by the substitution of revised plans of the same numbers, dated March, 1934. The revisions to the respective plans consist of the following:

Plan 780: Title revised to read:

Solid Manganese Steel Crossings for 7-in. and 9-in. Girder Rails
Steam Railroad over Electric Railway
(See note for Steam Railroad Tracks Both Ways)

Addition to the plan of the following note:

"When girder rail crossing carrying steam traffic over both runs is desired the details through both runs shall be in accordance with those here shown for "steam run" and the necessary joints within the diamond of the crossing shall accord with the details shown on Plan 771 for such joints.

"When it is desired to modify the arms to connect with 'T' rails, details for such arms should follow details prescribed on Plan 771.

"For complete rules for laying out details of crossing see Plan 700."

Plan 781: Title revised to read:

Solid Manganese Steel Crossings for 7-in. and 9-in. Girder Rails
Steam Railroad over Electric Railway
(See note for Steam Railroad Tracks Both Ways)

Addition to the present note on the plan of the following:

(The same information as given above for Plan 780.)

In addition to the above add to the note:

"If either track has a center line radius of less than 995-ft. (6 degrees) the end frogs must be suitably guarded on the curved track."

Plan 980: Note revised to read:

"For Straight Double Tongue Switches, suitable for situations where equipment having rigid wheel base of not more than 14 ft. 6 in. with two or three pairs of flanged wheels is used, see Plan 987.

"For Straight Double Tongue Switches, suitable for situations where equipment having rigid wheel base of not more than 19 ft. 0 in. with three, four or five pairs of flanged wheels is used, see Plan 988.

"For Curved Tongue Switch and Mate for industrial tracks, suitable for situations only where equipment having rigid wheel base with not more than two pairs of flanged wheels is used, see Plan 982."

The Committee recommends the revision of Plan 983, revised November, 1927, adopted March, 1928, and Plans 984, 985, and 986, dated November, 1927, adopted March, 1928, by the substitution of revised plans of the same numbers dated March, 1934. The revision to the respective plans consists of the addition to the note on each plan of the following:

"Wheel riser as per Plan 600–A shall be furnished when so specified."

Where necessary, the revisions to the plans referred to above shall include the showing of all dimensions less than 2 feet, in inches, and 2 feet and over, in feet and inches.

The Committee recommends the revision of Plan 982, dated February, 1930, adopted March, 1930, by the substitution of a revised plan of the same number, dated March, 1934.

The revisions consist of the following:

A. On General Plan—Switch:

(a) Changing dimension of 4 in. for width of tongue at 4 in. back from point end to 3 61/64 in.
(b) Deleting dimension of 1 in. for thickness of guard of tongue at Section C–C.
(c) Moving letters C–C for section to bend at 2 ft. 7 in. back from point of tongue.
(d) Adding note at line 1 ft. 4 in. back from point of tongue "Center line of lug if specified".
(e) Deleting the dimension of 1 in. for width of guard and 1 in. for opening between guard and switch piece at the bend near heel of switch.
(f) Changing dimension of 3 ft. 0⅞ in. distance from center of pin to bend to 3 ft. 6½ in.
(g) Adding dimension of 4 in. for distance from theoretical gage line to face of wall of switch piece at the bend 3 ft. 6½ in. from center of pin.
(h) Adding note "Face of wall of switch piece parallel with theoretical gage line and 4 in. therefrom".
(i) Change dimension of 1 in. for thickness of guard of tongue where it joins the heel of switch to ¾ in.
(j) Adding note "Switch for Right Hand Turnout as drawn".

B. On large size Section C–C deleting dimension of 1 in. for width of guard side of tongue and also deleting shade lines to indicate chamber.

C. On large detail drawing of point end of tongue:

(a) Moving letters C–C to 2 ft. 7 in. back from point of tongue at location marked "Bend".
(b) Adding dimension 3 61/64 in. for out to out width of tongue at 4 in. back from point end.

(c) Changing dimension of 1 in. for width of tongue on tread side 4 in. back from point end to 61/64 in. and correcting arrow for this dimension to extend to theoretical gage line of tongue instead of actual gage line as now shown on the plan.

D. On General Plan—Mate:

(a) Moving "BEND" on guard from 5 ft. 9 in. to 3 ft. 6 in. back from toe end and changing dimension 5 ft. 9 in. to 3 ft. 6 in.
(b) Moving dimension 2¼ in. for flangeway width from 5 ft. 9 in. to "BEND" at 3 ft. 6 in. back from toe end.
(c) Deleting the two dimensions 1¼ in. shown for distance from theoretical gage line in turnout run to guard line, between the "BEND" and the point of the mate.
(d) Changing dimension 4 ft. 5 in. to 4 ft. 4 in. Guard to Guard.
(e) Deleting the notation "P.C.C. on Guard" at point of mate, and the two radii of the guard, "Rad. 55′ 0″" and "Rad. 202′ 2¾″".
(f) Adding dimension 2¼ in. from theoretical gage line in turnout run to guard line, at 13/16 in. point of mate.
(g) Adding information to clearly show that between the "BEND" at toe end, and beginning of flare at heel end, the guard line is a 3 point curve, passing through the point 2¼ in. away from actual gage line at "BEND" 3 ft. 6 in. from toe end, the point 2¼ in. from theoretical gage line at 9 in. in from heel end, and the point 2¼ in. from theoretical gage line at 13/16 in. Point of Mate.
(h) Inserting word "ACTUAL" between "4′ 8¼″" and "GAGE" at dimension line 6 in. ahead of Point of Mate.
(i) Adding note "Mate for Right Hand Turnout as drawn".

E. In large detail of Mate Point, changing dimension 1¾ in. at end of Point in Turnout run to 2¾ in.

F. In Section E–E, changing 1¾ in. dimension for width of flangeway in turnout run to 2¾ in.

Where necessary the revisions referred to above, shall include the showing of all dimensions less than 2 feet, in inches and 2 feet and over in feet and inches.

The revised issue of the Portfolio of Trackwork Plans, available in the Secretary's office, include the plans with revisions above referred to.

Appendix B

(1–A) SPECIFICATIONS FOR SOFT STEEL TRACK SPIKES

E. D. Swift, Chairman, Sub-Committee; J. E. Deckert, F. J Jerome, F. H. Masters, E. M. T. Ryder, J. R. Scatterday.

The Committee offers the following additional sections for inclusion in the Specifications for Soft Steel Cut Track Spikes, now appearing in the Manual at page 252.

Tension Tests

(a) The manufacturer may, at his option, substitute tension tests for the chemical analysis specified in Section 2, in which case the finished spikes shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	55,000
Yield point, lb. per sq. in.	0.5 tensile strength
Elongation in 2 in., per cent	25

(b) When this option is exercised, one tension test shall be made from each 10-ton lot or fraction thereof.

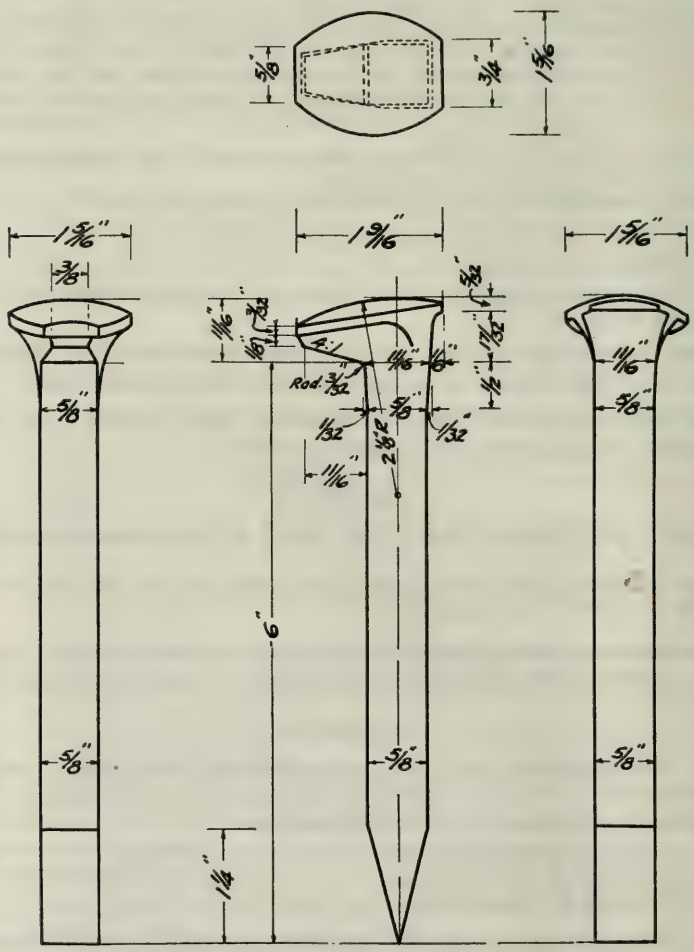
Copper Content

When copper is specified the percentage contained in the steel shall be not less than 0.20 of 1 per cent.

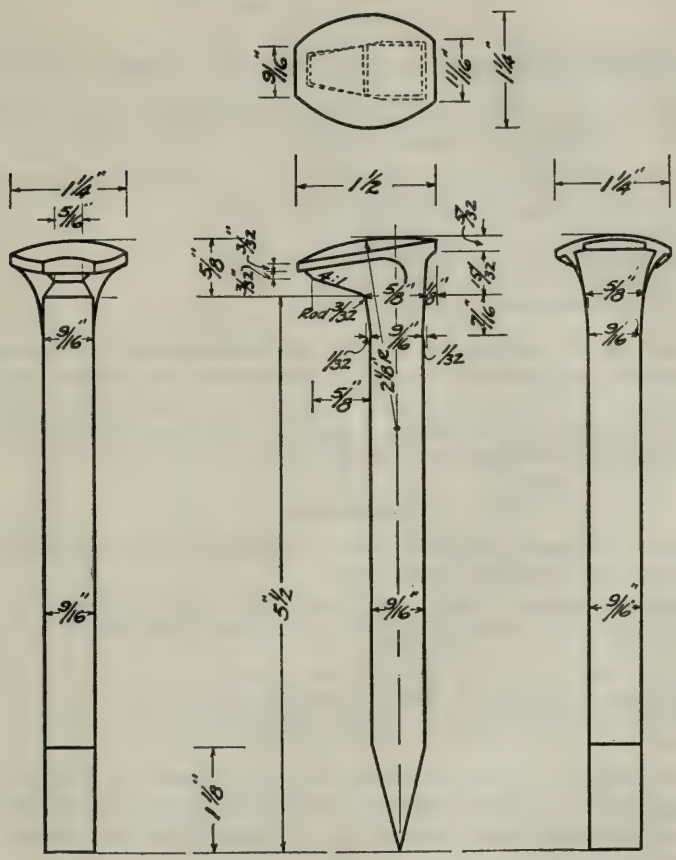
The Committee presents plans of $\frac{9}{16}$ in. and $\frac{5}{8}$ in. raised throat cut track spikes as information and for criticism pending their proposed later resubmission as recommended practice.

The Committee offers as information and for criticism pending its proposed resubmission as recommended practice a proposed revision of the Specifications now appearing in the Manual for Malleable Iron Tie Plates to consist of substituting the following requirements on tensile strength for the requirements now stated in the Specifications:

Tensile strength, lb. per sq. in.	53,000
Elongation in 2 inches, per cent	18
Yield point, lb. per sq. in.	35,000



5/8 Inch Raised Throat Track Spike.



9/16 Inch Raised Throat Track Spike.

Appendix C

(2) STRING LINING OF CURVES BY THE CHORD METHOD AND PREPARATION OF TABLES SUITABLE FOR THE USE OF TRACKMEN

C. M. McVay, Chairman, Sub-Committee; L. H. Bond, C. W. Breed, F. S. Hales, J. E. Hogan, E. T. Howson, C. J. Rist.

The Committee reports progress. Additional information on this subject is not developed sufficiently to warrant a report this year.

Appendix D

(3) PLANS AND SPECIFICATIONS FOR TRACK TOOLS

W. L. Roller, Chairman, Sub-Committee; W. H. B. Bevan, H. R. Clarke, L. W. Des-Lauriers, F. S. Hales, E. T. Howson, J. R. Scatterday, G. M. Strachan.

In the Proceedings, Vol. 31, 1930, pages 555 to 587 inclusive, the Committee submitted the following as information and for further study:

1. General Specification for Track Tools.
2. Specification for Hickory Handles for Track Tools.
3. Plan and Specification for Track Shovels.
4. Plan and Specification for Ballast Forks.

Since that time, in collaboration with the tool manufacturers, the Committee has revised these plans and specifications and now presents them for adoption and printing in the Manual.

Committee presents for information, a design for Frog and Crossing Limit Gage, together with instructions for the use of same.

Conclusions

Committee recommends for adoption as recommended practice and printing in the Manual the following Specifications and Plans:

1. General Specifications A.R.E.A. track tools, Plans A, B, C–1, and C–2.
2. Specifications for Hickory Handles A.R.E.A. Track Tools, Plans D–1, D–2, and D–3.
3. Specifications for A.R.E.A. Track Shovels, Plan E.
4. Specifications for A.R.E.A. Ballast Forks, Plan F.
5. Plan No. 21 dated Sept. 1933, A.R.E.A. Track Shovel.
6. Plan No. 22 dated Sept. 1933, A.R.E.A. Ballast Fork.

Committee wishes to submit following correction to report of 1930 Proceedings Vol. 31, page 587 in Conclusions "Plan 21 dated Sept. 1929 A.R.E.A.—Wooden Track Tool Handles" should be revised to read "Plan 25—Dated Sept. 1929, A.R.E.A. Track Tool Handles."

Committee submits a design of Frog and Crossing Limit Gage for use in maintenance in accordance with Plan 790 adopted in 1933 as a result of study made of Standard Wheel Flanges, Treads and Gages. The design (Plan 31) as submitted is to be used only at crossings and frogs to show proper gages for the use of chilled car wheels and heavy engine drivers.

The plan is submitted, along with instructions and study, Plans "A" and "B" for information only.

Committee recommends the subject be continued by making further study and design of additional tools adapted to use in modern track construction and maintenance, particularly as regards tools used in laying and handling of heavier rails.

INSTRUCTIONS FOR USING THE FROG AND CROSSING LIMIT GAGE AS OUTLINED ON A.R.E.A. PLAN NO. 790

(1) The Frog and Crossing "Limit Gage" is intended primarily to be used to check worn track at turnouts and crossings so that flangeways and guard rails may be maintained so that wheels properly gaged will pass freely without causing track distortion and without causing axles to be bent, or causing wheels to mount rails.

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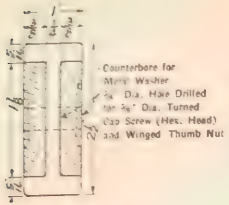
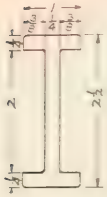
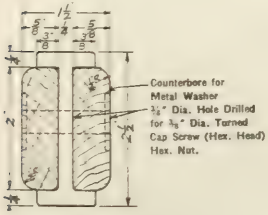


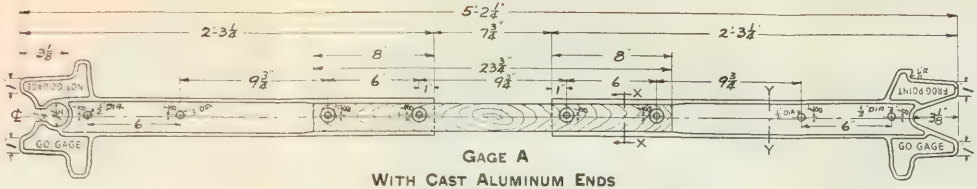
SECTION X-X



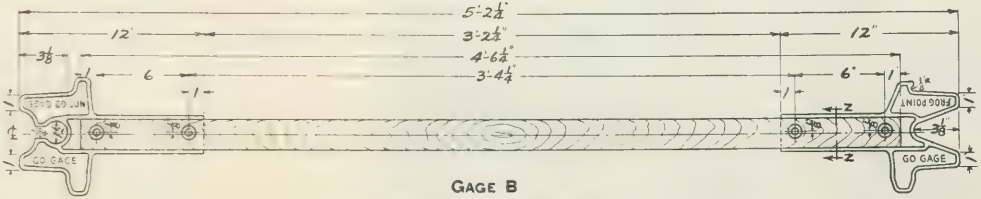
SECTION Y-Y



SECTION Z-Z



GAGE A
WITH CAST ALUMINUM ENDS



GAGE B
WITH CAST STEEL ENDS

NOTES

For dimensions not shown and for accurate finished dimensions required, see outline of Frog and Crossing Limit Gage, Plan No. 799.

Gage A may be taken down and assembled to a 2'-3¼" length with wood strips between the two cast aluminum ends, inserting the four cap screws through the four holes provided for this purpose.

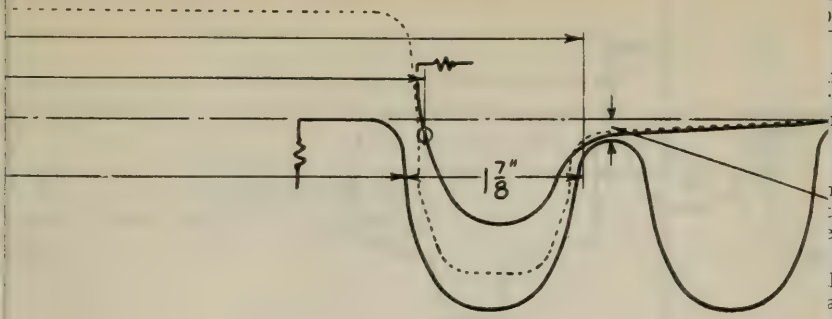
Wood strips shall be of mahogany or other approved hard wood.

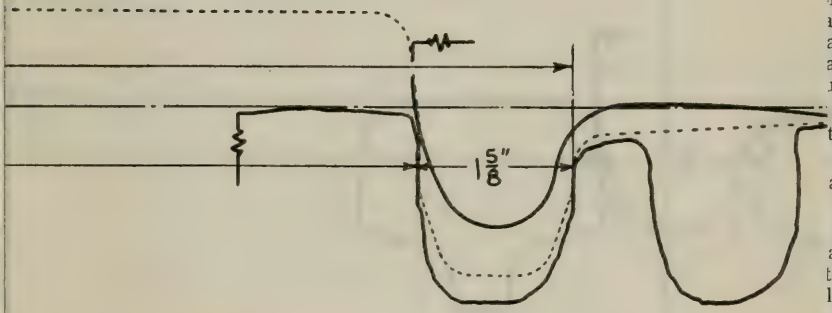
A. R. E. A.

FROG AND CROSSING LIMIT GAGES

STYLES A AND B

PLAN No. 31


$1\frac{7}{8}''$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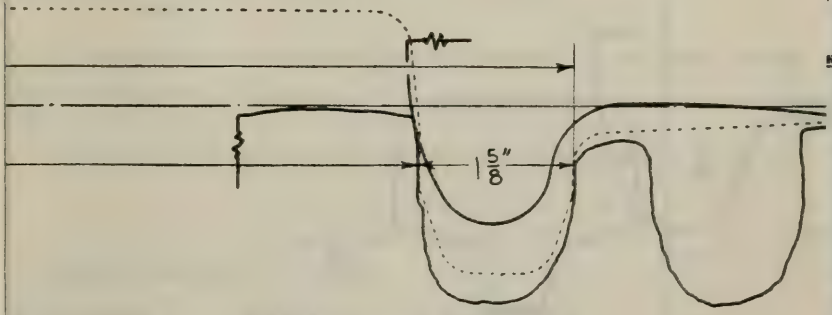

$1\frac{5}{8}''$

SECTIONS AT FROG POINT

DIAGRAM No. 1

A.R.A. STANDARD MOUNTED CAST IRON WHEELS NEW EQUIPMENT NEW STANDARD TRACK WITH OPEN HEARTH GUARD RAIL

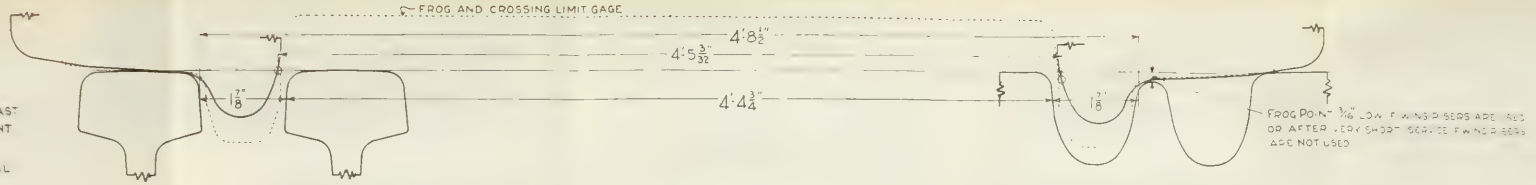


DIAGRAM No. 2

A.R.A. STANDARD CAST IRON WHEELS MOUNTED MINIMUM BACK TO BACK 4'-5", WITH TYPICAL ¼" TREAD WEAR TYPICAL WORN TRACK WITH FROG FLANGEWAY 1⅝"

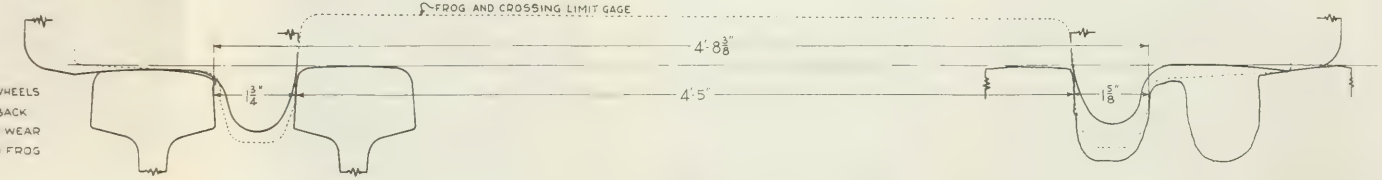
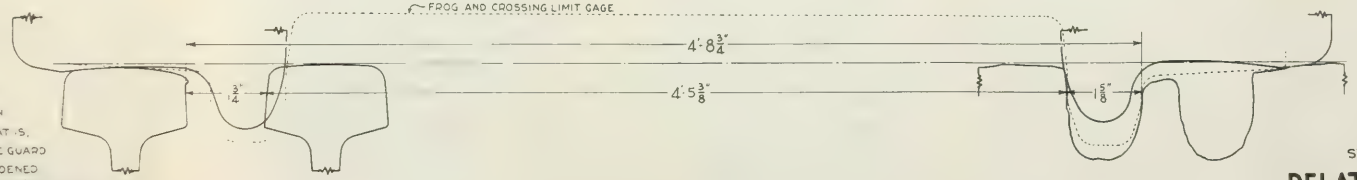


DIAGRAM No. 3

SHOWING WHAT TO AVOID IF RELAYING TRACK IN CONDITION SHOWN IN DIAGRAM No. 2 (THAT IS, WHEN THE GAGE IS WIDENED THE GUARD RAIL FLANGEWAY SHOULD BE WIDENED BY LIKE AMOUNT, MAKING SAME 2⅛" WIDE FOR 4'-8¾" TRACK GAGE IN THIS CASE)



STUDY PLAN "A"

RELATION OF NEW AND WORN WHEEL EQUIPMENT TO NEW AND WORN TRACK EQUIPMENT

SCALE, HALF SIZE (GAGE 4'-8½" MINUS 3'-0" + 1'-8½")

PLAN No. S-53310

SECTIONS AT FROG POINT

DIAGRAM No. 1

A.R.A. STANDARD MOUNTED CAST IRON WHEELS. NEW EQUIPMENT. NEW STANDARD TRACK WITH MANGANESE GUARD RAIL.

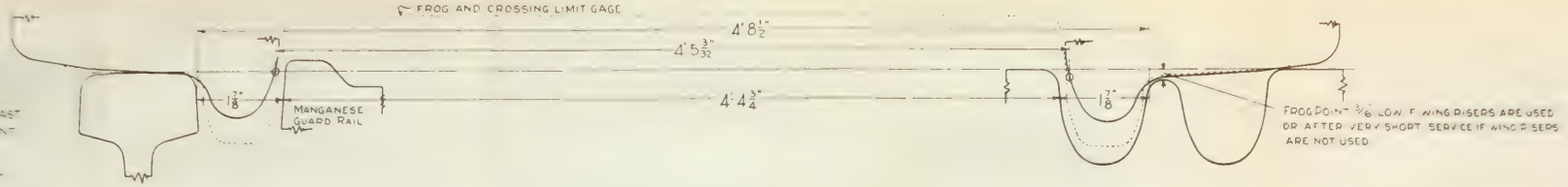


DIAGRAM No. 2

A.R.A. STANDARD CAST IRON WHEELS MOUNTED MINIMUM BACK TO BACK 4'-5" WITH TYPICAL TREAD WEAR. TYPICAL WORN TRACK WITH FROG FLANGEWAY ⅝"

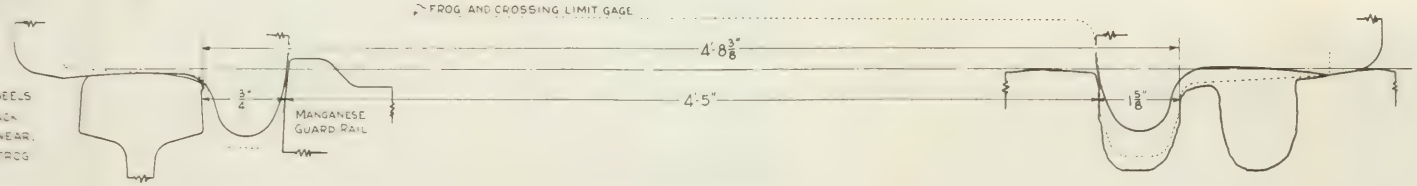
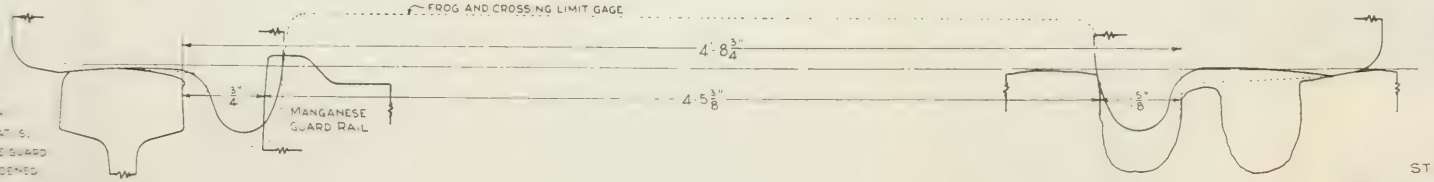


DIAGRAM No. 3

SHOWING WHAT TO AVOID IF RELINING TRACK IN CONDITION SHOWN IN DIAGRAM No. 2 (THAT IS, WHEN THE GAGE IS WIDENED THE GUARD RAIL FLANGEWAY SHOULD BE WIDENED BY THE AMOUNT MAKING SAME 2⅛" WIDE FOR 4' 8½" TRACK GAGE IN THIS CASE)

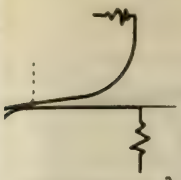


STUDY PLAN "B"

RELATION OF NEW AND WORN WHEEL EQUIPMENT TO NEW AND WORN TRACK EQUIPMENT

SCALE, HALF SIZE (GAGE 4' 8½" MINUS 3' 0" = 1' 8½")

PLAN No. S-93310



FROG POINT 3/16" LOW IF WING RISERS ARE USED OR AFTER VERY SHORT SERVICE IF WING RISERS ARE NOT USED

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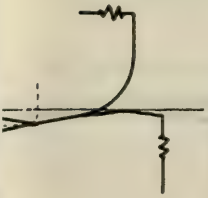

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STUDY PLAN "B"

RELATION OF NEW AND WORN WHEEL EQUIPMENT TO NEW AND WORN TRACK EQUIPMENT

SCALE, HALF SIZE (GAGE 4'-8½" MINUS 3'-0" = 1'-8½")

PLAN No. S-93310

(2) The "NOT GO" gage, illustrated in the upper half of the Frog and Crossing Limit Gage is similar to a standard gage used for setting guard rails to protect the frog point. When "frog point end" is in contact with the worn frog, the guard rail end must "NOT GO" into flangeway.

(3) The "GO GAGE", illustrated in the bottom half of the gage, will fit freely in new track work properly installed, or in worn track work where the flangeways are not less than 1⅝ in. wide, and the guard face gage does not exceed 4 ft. 5 in., and where the track gage is not less than 4 ft. 8¼ in. These have been accepted as the limiting dimensions for properly maintaining worn track.

(4) In checking crossings (especially those near 90 degree intersection angle), this "GO GAGE" will readily detect flangeways which should be ground out to maintain the proper clearance. The tendency is for the flangeways in crossings to narrow at intersections, due to the flow of metal from the tread surfaces. This is especially noticeable where traffic predominates over one line, and the flangeways on the less used track line close.

(5) Attention to the correct adjustment of the guard rail opposite the frog point of turnout will permit the frog flangeways to close-in to 1⅝ inches width without track distortion resulting when wheels pass through. This is clearly exhibited on study plans "A" and "B", showing conditions with open-hearth guard rails of T rail head and manganese guard rails having a head of special form approximately ¼ in. higher than running rail.

Diagram 1 in each case shows the frog and crossing limit gage fitting freely into the flangeways of the new track.

Diagram 2 in each case shows the guard rail properly set for 1⅝ in. frog flangeway, and the frog and Crossing Limit Gage fitting into the flangeways.

Diagram 3 in each case shows what to avoid if relining track in condition shown in diagram 2. If the gage is widened and the guard rail is pulled out with the track rail, an excessive "guard-face-gage" (as shown in this diagram) will result; in this case it is evident that track distortion will occur when every pair of wheels passes through, unless the wheels climb or their axles bend.

PLAN A

INDEX

PLAN NO.	DESCRIPTION	GRADE STEEL	BRINELL AND ROCKWELL HARDNESS
A	Index		
B	General Specifications		
C-1-2	Inspection & Physical Tests		
D-1-2-3	Wooden Handle Specifications		
E	Track Shovel Specifications		
F	Ballast Fork Specifications		
1	Clay Pick	O.H. or Alloy *	425-500
2	Tamping Pick	O.H. or Alloy *	425-500
3	Spike Maula-No. 1 and No. 2	O.H. or Alloy *	425-500
4	Track Wrenches	O.H.	375-450
5	Lining Bars	O.H.	425-500
6	Rail Tongs	O.H.	None
7	Tie Tongs	O.H.	None
8	Timber Tongs	O.H.	None
9	Spike Puller	O.H.	375-450
10	Rail Fork	O.H.	None
11	Claw Bars - No. 1 and No. 2	O.H.	300-375
12	Track Adze	O.H. or Alloy *	375-450
13	Double Faced Sledge	O.H. or Alloy *	425-500
14	Chisel End Tamping Bar	O.H.	425-500
15	Spear End Tamping Bar	O.H.	425-500
16	Track Chisel No. 1	Elec. or Alloy *	Point 477-532 Head 286-340
17	Track Chisel No. 2	Alloy *	
18	Tie Plug Punch	Electric	Point 477-532 Head 286-340
19	Round Track Punch	Electric	Point 477-532 Head 286-340
20	Track Gage	Cast	None
21	Track Shovels	O.H. or Alloy *	40-45 (Rockwell) 258-331
22	Ballast Forks		
25	Wooden Track Tool Handles		

* No Hardness Specification for Alloy Steel.

Plan B

TRACK TOOLS

GENERAL SPECIFICATIONS

WORKMANSHIP AND FINISH:

Each tool shall be finished in a workmanlike manner and shall be free from seams, cracks, irregularities of shape and other imperfections. Before leaving the factory, each tool shall be coated with paint, oil or varnish to prevent corrosion, and each polished cutting edge shall be oiled.

MARKING:

Each tool shall be plainly stamped with the manufacturer's name or brand and the purchaser's initials.

INSPECTION AND TESTS:

Inspection of finished tools may, at the option of the purchaser, be made at the plant prior to shipment and the manufacturer shall afford the inspector, free of cost, all reasonable facilities to enable him to satisfy himself that the tools are in accordance with the plans and specifications. The tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works. Unless otherwise specified, the inspector shall select and test one finished tool from each lot of ten dozen or less, and the acceptance or rejection of each lot shall be determined by the results of this test.

In the detail specifications, the permissible variations are not to be construed to change the shape and general contour of the tool as indicated on the plans.

When Brinell hardness tests are specified, other recognized bases of measurement may be used, provided equal results are obtained.

SHIPMENT OR DELIVERY:

Tools shall be properly packed for shipment to avoid damage. All bundles and boxes shall be plainly marked with the name of the purchaser, the name of the manufacturer, and the point of shipment.

MANUFACTURER'S GUARANTEE:

The manufacturer shall guarantee that all tools are free from defects in material and workmanship and shall replace any tools found to be defective.

Plan C-1

INSPECTION AND PHYSICAL TESTS

CLAY PICK - PLAN NO. 1: (Open Hearth Steel or Alloy*)

Dimensions, length, size of eye and curve or anchor of pick to be as shown on the plan. Brinell 425 to 500 at a point 1-1/2" from each end.

TAMPING PICK - PLAN NO. 2: (Open Hearth Steel or Alloy*)

Dimensions, length, size of eye and curve or anchor of pick as shown on plan. Brinell 425 to 500 at a point 1-1/2" from each end.

SPIKE MAULS - PLAN NO. 3: (Open Hearth Steel or Alloy*)

Dimensions, length, striking ends and eye as shown on plan. Brinell 425 to 500, 1/2" back of face of each end. Sample of each lot of twenty dozen or less to be subjected to 1,000 full swinging blows for open hearth steel and 3,000 full swinging blows for alloy steel by continuous hand striking or the mechanical equivalent on a die block of Brinell 400, without undue mushrooming or cracking of the face or edge of mushroom.

TRACK WRENCHES - PLAN NO. 4: (Open Hearth Steel)

Dimensions as shown on plan. Brinell 375 to 450 at a point 1/2" back from the extreme face of the working end of wrench. One wrench to be tested from each lot of ten dozen or less by applying for one minute a load of 400 lbs at a point distant from the jaw end equal to 95% of the total length of the wrench without any spreading of the jaw or any permanent set in the handle.

LINING BARS - PLAN NO. 5: (Open Hearth Steel)

Dimensions, length, size and shape of point as shown on plan. Brinell 425 to 500 at a point 1-1/2" from end. One bar to be tested from each lot of ten dozen or less by applying a load of 350 lbs. 12" from the end of the handle, with the point suitably secured 3" from the end, without leaving a permanent set in excess of 1/4".

RAIL TONGS - PLAN NO. 6: (Open Hearth Steel)

Dimensions as shown on plan.

TIE TONGS - PLAN NO. 7: (Open Hearth Steel)

Dimensions as shown on plan.

TIMBER TONGS - PLAN NO. 8: (Open Hearth Steel)

Dimensions as shown on plan.

SPIKE PULLER - PLAN NO. 9: (Open Hearth Steel)

Dimensions as shown on plan. Brinell 375 to 450, 1/2" from point of jaw. Sample of each lot manufactured to be tested in actual use by pulling a spike with a standard claw bar.

RAIL FORK - PLAN NO. 10: (Open Hearth Steel)

Dimensions as shown on plan.

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* No Hardness Specifications for Alloy Steel.

PLAN C-2

CLAW BAR - PLAN NO.11: (Open Hearth Steel)
Dimensions of claw, depth of heel, length and sectional dimension of handle as shown on plan. Brinell 300-375. One bar from each lot of 20 dozen or less to be tested by placing the claws of the bar ½" under the head of a standard track spike, rigidly placed and so located as to hold the bar in a horizontal position while a shock load equivalent to that of a 200 lb. weight falling a distance of one foot is applied to the handle at a point 5" from its end, without the toes showing any cracks or the handle taking any permanent set.

TRACK ADZE - PLAN NO.12: (Open Hearth or Alloy Steel*)
Dimensions and detail of eye as shown on plan. Brinell 375 to 450, 2" from cutting edge. Test one adze in each lot of twenty dozen or less by subjecting cutting edge to five blows on metal of the same composition as a railroad spike without breakage or serious nicking.

SLEDGE - PLAN NO.13: (Open Hearth or Alloy Steel*)
Dimensions and detail of eye as shown on plan. Brinell 425 to 500 ⅛" back of face of the sledge. Sample of each lot of twenty dozen or less to be subjected to 1,000 full swinging blows for open hearth steel or 3,000 full swinging blows for alloy steel by continuous hand striking or the mechanical equivalent on a die block of Brinell 400, without undue mushrooming or cracking of the face or edge of mushroom.

TAMPING BAR - PLANS NOS.14-15: (Open Hearth Steel)
Dimensions as shown on plan. Brinell 425 to 500, ⅛" from working edge or face.

TRACK CHISEL, DESIGN NO.1 - PLAN NO.16: (Electric or Alloy Steel*)
Dimensions and detail of eye as shown on plan. Brinell at a point ½" back from cutting edge, 477 to 532; at head ½" from striking face, 286 to 340. One chisel in each lot of twenty dozen or less to be tested by cutting 100 linear inches in a rail head of Brinell 260 by mechanical or hand striking approximating service conditions, to a depth of 3/16" below original surface; in addition, striking three gouging blows of such intensity as to give for each blow a cut of approximately 1/16" in depth. The chisel point shall stand this test uninjured and the head shall stand up without undue battering.

TRACK CHISEL, DESIGN NO.2 - PLAN NO.17: (Alloy Steel Only*)
Dimensions and detail of eye as shown on plan.

TIE PLUG PUNCH - PLAN NO.18 AND ROUND TRACK PUNCH - PLAN NO.19:
Dimensions and detail of eye as shown on plan. Brinell 477 to 532, at a point ½" from working end: 286 to 340 at a point ½" from striking face.

TRACK GAGE - PLAN NO.20:
Dimensions as shown on plan. No tolerance allowed in gage distance.

* No Hardness Specifications for Alloy Steel

PLAN D-1

A.R.E.A. SPECIFICATIONS FOR HICKORY HANDLES FOR TRACK TOOLS

Handles 24" and longer shall conform to "Grades AA, AW or AR"; handles less than 24" to "Grades SAW or SAR" as set forth in Simplified Practice Recommendation No. 77 of the Bureau of Standards, U. S. Department of Commerce, effective November 1st, 1927.

DESIGN:
Handles shall conform to the dimensions shown on the plan forming part of this specification, with an allowable variation of one-quarter inch in length, and one-sixteenth inch over or under for all other dimensions. Eyes and dimensions of such handles are in accord with Simplified Practice Recommendation No. 17 - Forged Tools, Bureau of Standards, U.S. Department of Commerce, effective April 1st, 1927.

PHYSICAL REQUIREMENTS:
Handles shall be smooth, straight and for each type of tool, uniform in size and shape. Handles must be properly seasoned. The grain of the wood must run parallel to the center line of the handle, with an allowable variation of not over one inch in fifty inches. Handles which are warped or twisted shall not be accepted.

MANUFACTURE:
(a) Handles shall be smoothly finished and waxed.
(b) Each handle shall be plainly marked for identification by the purchaser, with brand and identification mark, as specified by Simplified Practice Recommendation No. 77. Marking, unless otherwise specified by purchaser, shall be placed near the hand grasp end of handles and letters must not be less than three-eighths inch in height.

INSPECTION:
(a) Handles will be inspected at points of manufacture, shipment or destination in suitable and convenient places satisfactory to the purchaser.
(b) Inspectors representing the purchaser shall have free entry to the works of the manufacturer at all times while work on the contract of the purchaser is being performed, and shall have all reasonable facilities afforded them, free of cost, to satisfy them that the handles are being supplied in accordance with these specifications.
(c) Inspectors will make a reasonably close examination of each handle and the acceptance or rejection will be based on the inspector's knowledge of the appearance, weight and density required; rings of annual growth will not be counted nor handles weighed by scale unless the inspector's decisions are questioned. Exactness of size and shape will be checked by accurate measurements of handles taken at random.

DELIVERY:
Accepted handles shall be shipped by the seller in accordance with the instructions in the order covering them; they shall be securely packed in standard packages, each of which shall be marked to show seller's or manufacturer's name and the number, type and grade of the handles contained.

PLAN D-2

GRADE CLASSIFICATION FOR HANDLES, PLAN NUMBER REFERENCE AND MAXIMUM AND MINIMUM WEIGHTS PER DOZEN

	Weights per Dozen	
	Min.	Max.
GRADE "AA"		
Spike Maul - Plan No. 3.	14½#	17#
Sledge - Plan No. 13	15#	18#
GRADE "AW" or "AR" *		
Axe - No Plan	17#	20#
Adz - Plan No. 12	15#	18#
Pick, Clay - Plan No. 1	21#	26#
Pick, Tamping - Plan No. 2	21#	26#
GRADE "SAW" or "SAR" **		
Track Chisels - Plan Nos. 16 & 17	7½#	11#
Tie Plug Punch - Plan No. 18	7½#	11#
Track Punch - Plan No. 19	7½#	11#

* Note; - Grade "BW" or "BR" may be furnished in lieu of Grade "AW" or "AR" if lower grade of handle is desired.

** Note; - Grade "SBW" or "SBR" may be furnished in lieu of Grade "SAW" or "SAR" if a lower grade of handle is desired.

PLAN D-3

DEFINITION OF GRADES - HICKORY HANDLES

TAKEN FROM SIMPLIFIED PRACTICE RECOMMENDATIONS NO. 77 - U.S. DEPARTMENT OF COMMERCE

Handles 24" and Longer

GRADE AA

Handles having not over 17 rings of annual growth per inch of radius; heavy weight, thrifty growth, all white, free from defects.

GRADES AW AND AR

Handles having not over 22 rings of annual growth per inch of radius, good weight, live growth, free from all defects. Handles of this grade will be supplied in all white wood, the grade symbol being AW; or in red, white, or mixed red and white, for which the symbol will be AR.

GRADES BW AND BR

Handles having not over 27 rings of annual growth per inch of radius, good weight, live growth. These grades permit such handles as have slight iron streaks not exceeding four in number running the entire length of the handle or the equivalent in shorter lengths. To be free from defects except in the first third of the length from the grasp end, or in the eye where is permitted one sound or tight knot or bird peck not over one-fourth inch in diameter or two such knots or bird pecks where combined diameters do not exceed one-fourth inch in diameter or slight deflection of grain. Handles of this grade will be supplied in white wood, the grade symbol being BW; or in red, white, or mixed red and white, for which the symbol will be BR.

Handles Less than 24" in Length

GRADES SAW AND SAR:

Handles having not over 17 rings of annual growth per inch of radius, heavy weight, thrifty growth, free from all defects. Handles of this grade will be supplied in all white wood, the grade symbol being SAW; or in red, white, or mixed red and white, for which the symbol will be SAR.

GRADES SBW AND SBR:

Handles of medium weight, live growth, permitting two slight iron streaks the entire length, or their equivalent in shorter streaks. Free from all defects. Handles of this grade will be supplied in all white wood, the grade symbol being SBW; or in red, white, or mixed red and white, for which the symbol will be SBR.

PLAN E

AREA SPECIFICATION FOR TRACK SHOVELS

(See General Specifications)

SCOPE AND DESIGN

This specification covers both the welded or riveted type and the solid shank type with either wood, malleable iron or combination wood-metal handle tops. Dimensions shall conform to plans, which are made a part of this specification. A variation of one-half inch more or less from the dimension shown on plan for length of strap or shank and handle will be allowed, but the total variation in length of shovels shall not exceed one inch. Width or length of blade may vary 1/4" over or under.

MATERIALS

Blades shall be of open hearth, crucible, electric furnace or alloy steel, with Rockwell hardness for carbon steel of 40 to 45.

Carbon steel blades shall be in thickness not less than #13 gauge and alloy blades shall be of not less than #14 gauge U.S.Standard. For welded or riveted type, the straps shall be welded or riveted to the blade.

HANDLES AND TOPS

Handles shall be made of White Ash and shall conform to "Grade XX" as set forth in Simplified Practice Recommendation No. 76 of the Bureau of Standards, U.S.Department of Commerce. Handles shall be uniform in size and shape, thoroughly air seasoned and smoothly finished. Tops of handles shall be of the design ordered and shall conform to plans that are made a part of this specification.

TESTS

One shovel from each lot of ten dozens or less shall be selected and metal straps (curved to fit contour of handle) shall be clamped to the upper and lower parts of the handle, after which the shovel shall be placed in a prying position. supported at the end of the blade by clamps and shall be capable of sustaining a load of 200 lbs. suspended from the end for a period of two minutes without showing any permanent set, fracture or distortion.

Alloy steel shovels which have been given a heat treatment to insure uniformity in hardness shall be subjected to a shock test to insure against brittleness. The test shall be made by forcibly striking the blade of the shovel with a hand hammer at several places when placed on an anvil.

PLAN F

AREA SPECIFICATIONS FOR BALLAST FORKS

(See General Specifications)

DESIGN

Dimensions of forks shall conform to plan which is made a part of this specification.

MATERIALS

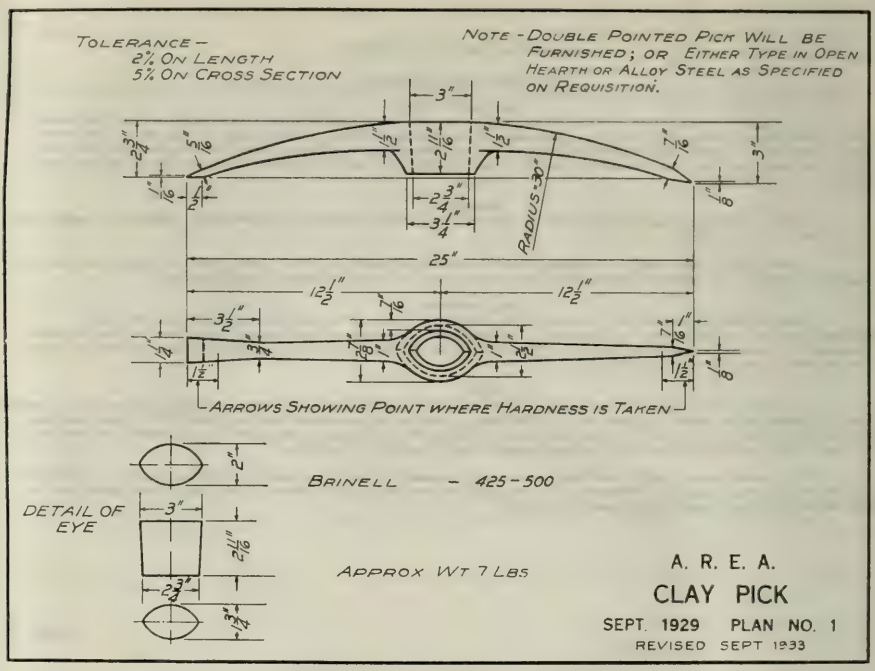
Forks shall be made of high grade Open Hearth Steel.

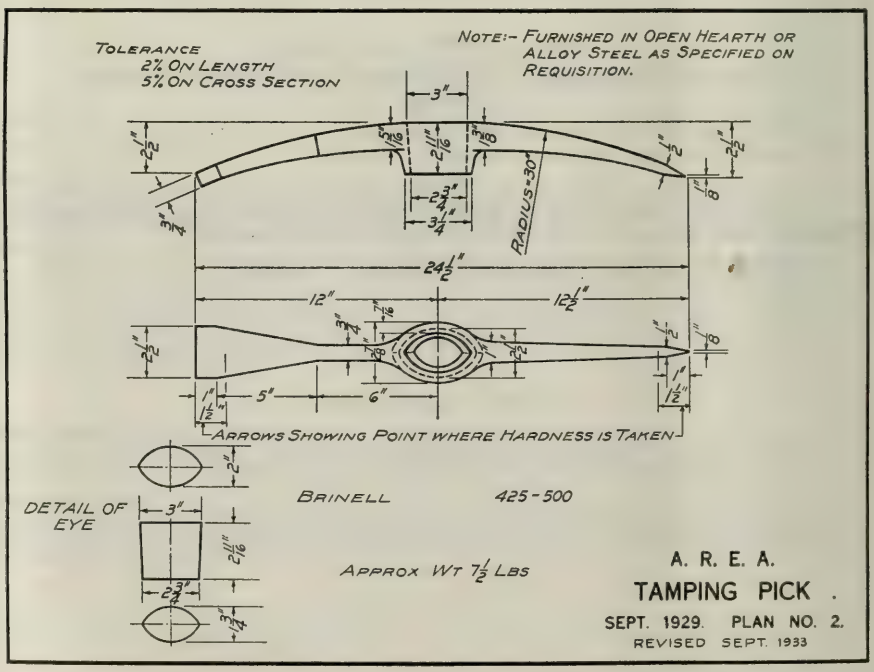
Tines of forks shall show Brinell hardness of 259 to 331.

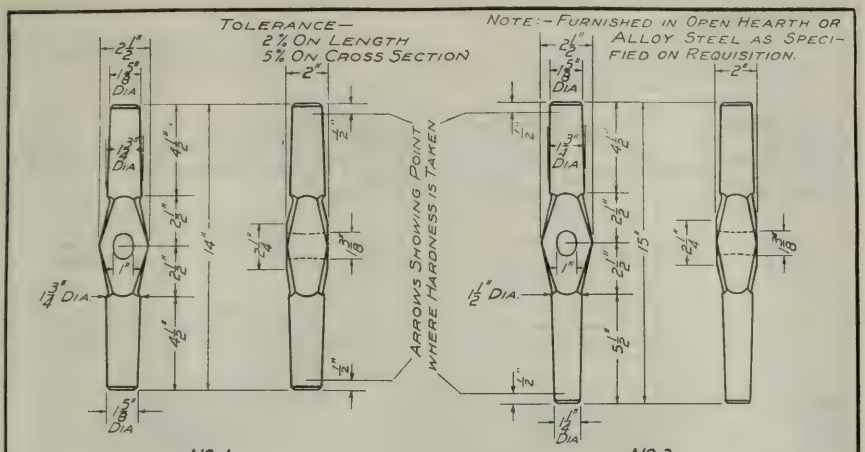
HANDLES

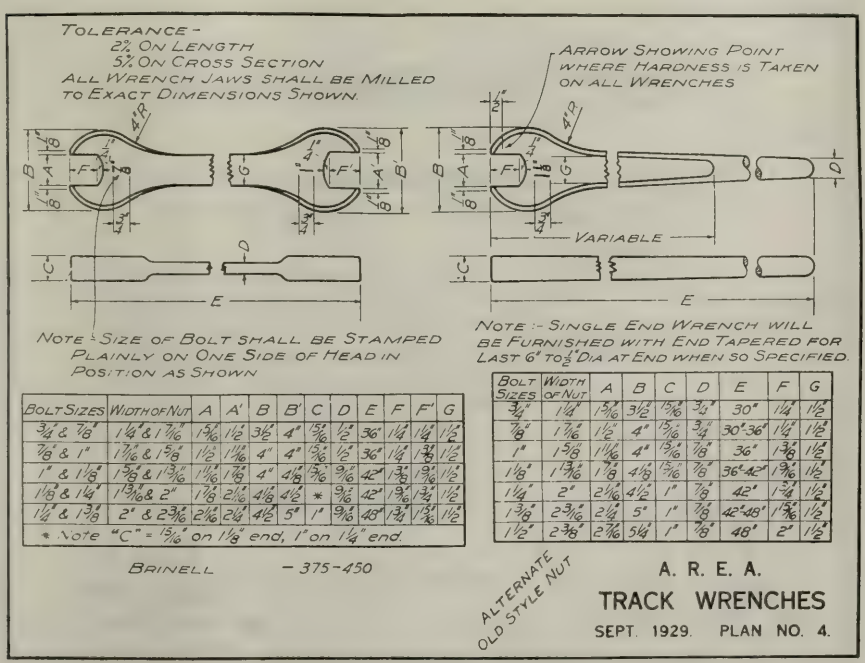
Handles shall be made of White Ash and shall conform to "Grade XX" as set forth in Simplified Practice Recommendation No. 76 of the Bureau of Standards, U. S. Department of Commerce. Handles shall be straight, uniform in size and shape, thoroughly seasoned and smoothly finished.

Permissible variation in overall length of tool shall not exceed ½"


TOLERANCE –
2% ON LENGTH
5% ON CROSS SECTION
NOTE - DOUBLE POINTED PICK WILL BE FURNISHED; OR EITHER TYPE IN OPEN HEARTH OR ALLOY STEEL AS SPECIFIED ON REQUISITION.
RADIUS = 30"
25"
ARROWS SHOWING POINT WHERE HARDNESS IS TAKEN
DETAIL OF EYE
BRINELL – 425 - 500
APPROX WT 7 LBS
A. R. E. A.
CLAY PICK
SEPT. 1929 PLAN NO. 1
REVISED SEPT 1933


TOLERANCE
2% ON LENGTH
5% ON CROSS SECTION
NOTE:- FURNISHED IN OPEN HEARTH OR ALLOY STEEL AS SPECIFIED ON REQUISITION.
RADIUS = 30"
24½"
ARROWS SHOWING POINT WHERE HARDNESS IS TAKEN
DETAIL OF EYE
BRINELL 425 - 500
APPROX WT 7½ LBS
A. R. E. A.
TAMPING PICK
SEPT. 1929. PLAN NO. 2.
REVISED SEPT. 1933





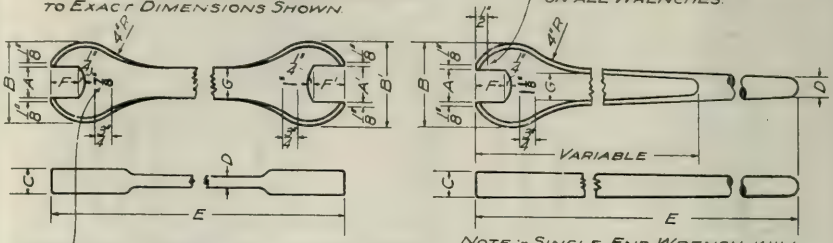
BOLT SIZES	WIDTH OF NUT	A	A'	B	B'	C	D	E	F	F'	G
3/4" & 7/8"	1 1/4" & 1 7/16"	1 5/16"	1 1/2"	3 1/2"	4"	15/16"	1/2"	36"	1 1/4"	1 1/4"	1 1/2"
7/8" & 1"	1 7/16" & 1 5/8"	1 1/2"	1 11/16"	4"	4"	15/16"	1/2"	36"	1 1/4"	1 3/8"	1 1/2"
1" & 1 1/8"	1 5/8" & 1 13/16"	1 11/16"	1 13/16"	4"	4 1/8"	15/16"	9/16"	42"	1 3/8"	1 9/16"	1 1/2"
1 1/8" & 1 1/4"	1 13/16" & 2"	1 7/8"	2 1/16"	4 1/8"	4 1/2"	*	9/16"	42"	1 9/16"	1 3/4"	1 1/2"
1 1/4" & 1 3/8"	2" & 2 3/16"	2 1/16"	2 1/4"	4 1/2"	5"	1"	9/16"	48"	1 3/4"	1 15/16"	1 1/2"

* Note "C" = 15/16" on 1 1/8" end, 1" on 1 1/4" end.

BOLT SIZES	WIDTH OF NUT	A	B	C	D	E	F	G
3/4"	1 1/4"	1 5/16"	3 1/2"	15/16"	3/4"	30"	1 1/4"	1 1/2"
7/8"	1 7/16"	1 1/2"	4"	15/16"	3/4"	30"-36"	1 1/4"	1 1/2"
1"	1 5/8"	1 11/16"	4"	15/16"	7/8"	36"	1 3/8"	1 1/2"
1 1/8"	1 13/16"	1 7/8"	4 1/8"	15/16"	7/8"	36"-42"	1 9/16"	1 1/2"
1 1/4"	2"	2 1/16"	4 1/2"	1"	7/8"	42"	1 3/4"	1 1/2"
1 3/8"	2 3/16"	2 1/4"	5"	1"	7/8"	42"-48"	1 15/16"	1 1/2"
1 1/2"	2 3/8"	2 7/16"	5 1/4"	1"	7/8"	48"	2"	1 1/2"

TOLERANCE –
2% ON LENGTH
5% ON CROSS SECTION
ALL WRENCH JAWS SHALL BE MILLED TO EXACT DIMENSIONS SHOWN.

ARROW SHOWING POINT WHERE HARDNESS IS TAKEN ON ALL WRENCHES.



NOTE:- SIZE OF BOLT SHALL BE STAMPED PLAINLY ON ONE SIDE OF HEAD IN POSITION AS SHOWN.

NOTE:- SINGLE END WRENCH WILL BE FURNISHED WITH END TAPERED FOR LAST 6" TO ½" DIA. AT END WHEN SO SPECIFIED.

BOLT SIZES	WIDTH OF NUT	A	A'	B	B'	C	D	E	F	F'	G
3/4" & 7/8"	1 1/8" & 1 5/16"	1 3/16"	1 3/8"	3 3/8"	3 7/8"	15/16"	1/2"	36"	1 1/8"	1 1/8"	1 1/2"
7/8" & 1"	1 5/16" & 1 1/2"	1 3/8"	1 9/16"	3 7/8"	3 7/8"	15/16"	1/2"	36"	1 1/8"	1 1/4"	1 1/2"
1" & 1 1/8"	1 1/2" & 1 11/16"	1 9/16"	1 3/4"	3 7/8"	4"	15/16"	9/16"	42"	1 1/4"	1 7/16"	1 1/2"
1 1/8" & 1 1/4"	1 11/16" & 1 7/8"	1 3/4"	1 15/16"	4"	4 3/8"	*	9/16"	42"	1 7/16"	1 5/8"	1 1/2"
1 1/4" & 1 3/8"	1 7/8" & 2 1/16"	1 15/16"	2 1/8"	4 3/8"	4 7/8"	1"	9/16"	42"	1 5/8"	1 13/16"	1 1/2"
* Note "C" = 13/16" on 1 1/8" end, 1" on 1 1/4" end.											

BRINELL – 375-450

GENERAL NOTE – ABOVE JAW OPENINGS DESIGNED TO FIT NEW A.S.A. NUTS – Jan 1930

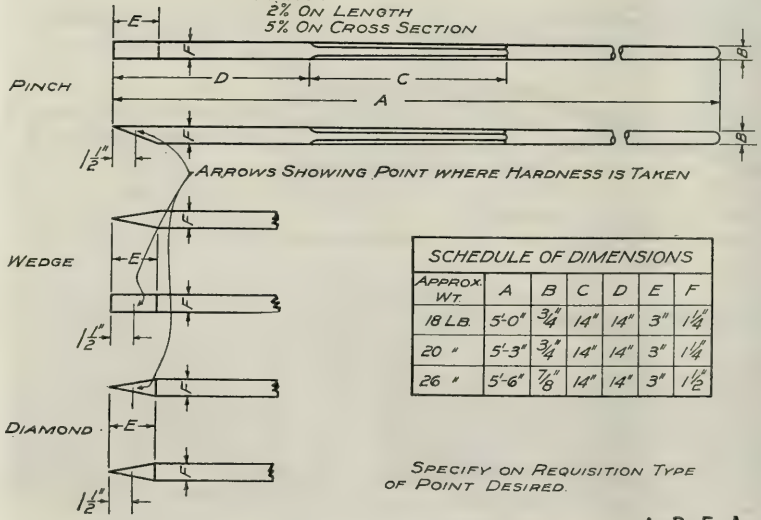
BOLT SIZES	WIDTH OF NUT	A	B	C	D	E	F	G
3/4"	1 1/8"	1 13/16"	3 3/8"	15/16"	3/4"	30"	1 1/8"	1 1/2"
7/8"	1 5/16"	1 7/8"	3 7/8"	15/16"	3/4"	30"-36"	1 1/8"	1 1/2"
1"	1 1/2"	1 9/16"	3 7/8"	15/16"	7/8"	36"	1 1/4"	1 1/2"
1 1/8"	1 11/16"	1 3/4"	4"	15/16"	7/8"	36"-42"	1 7/16"	1 1/2"
1 1/4"	1 7/8"	1 15/16"	4 3/8"	1"	7/8"	42"	1 5/8"	1 1/2"
1 3/8"	2 1/16"	2 1/8"	4 7/8"	1"	7/8"	42"-48"	1 13/16"	1 1/2"
1 1/2"	2 1/4"	2 5/16"	5 1/8"	1"	7/8"	48"	1 7/8"	1 1/2"

A. R. E. A.

TRACK WRENCHES

FEB. 1930. PLAN NO. 4-A

TOLERANCE –
2% ON LENGTH
5% ON CROSS SECTION



SCHEDULE OF DIMENSIONS						
APPROX. WT.	A	B	C	D	E	F
18 LB.	5'-0"	3/4"	14"	14"	3"	1 1/4"
20 "	5'-3"	3/4"	14"	14"	3"	1 1/4"
26 "	5'-6"	7/8"	14"	14"	3"	1 1/2"

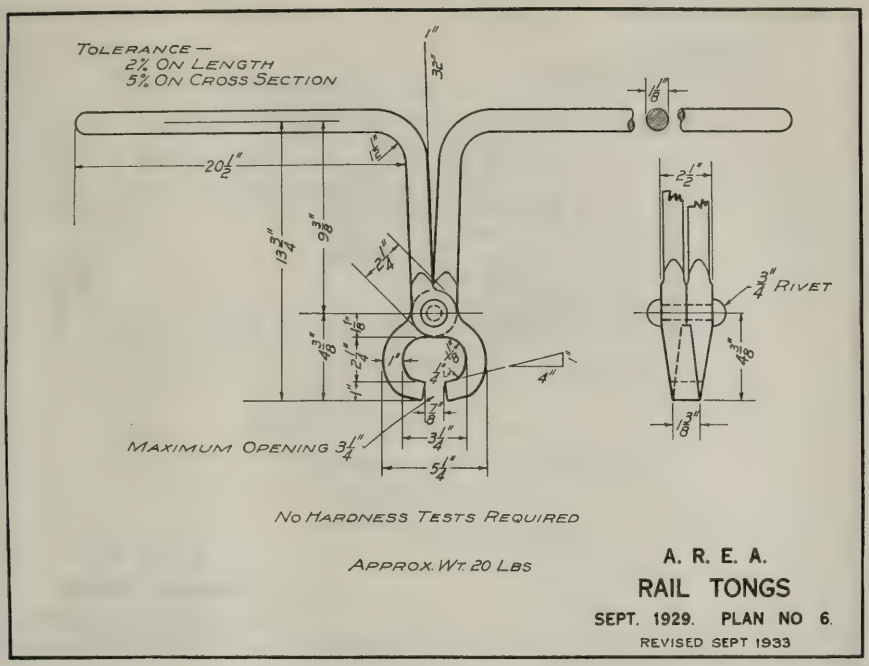
SPECIFY ON REQUISITION TYPE OF POINT DESIRED.

BRINELL – 425-500

A. R. E. A.

LINING BAR

SEPT. 1929. PLAN NO. 5.
REVISED NOV. 1933

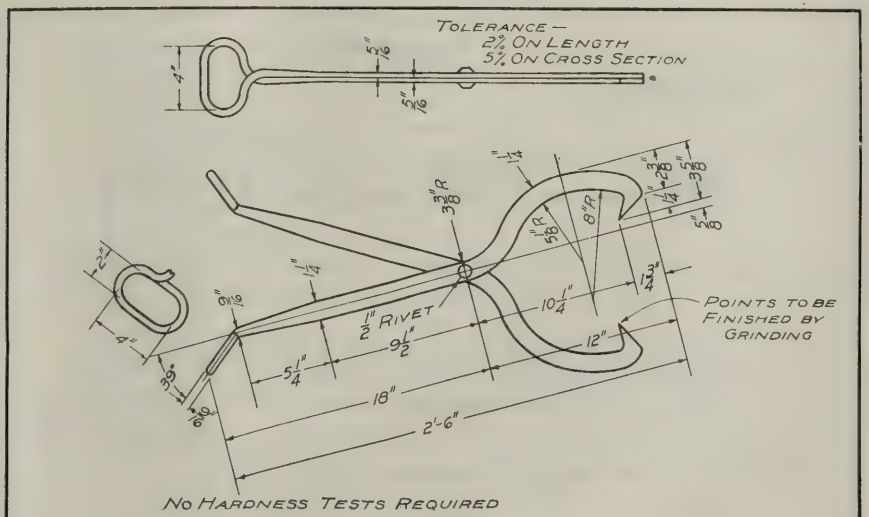


A. R. E. A.

RAIL TONGS

SEPT. 1929. PLAN NO 6.

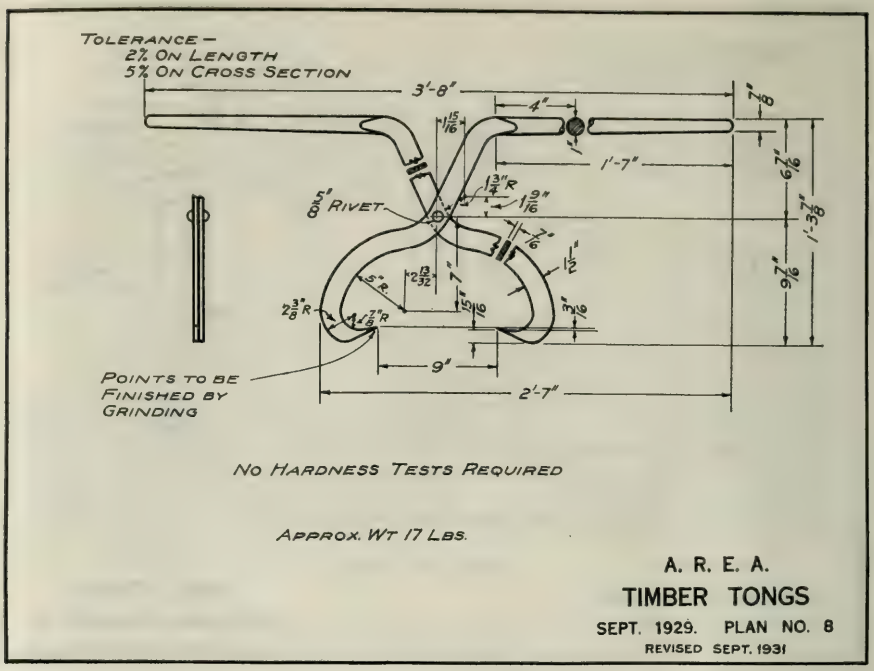
REVISED SEPT 1933

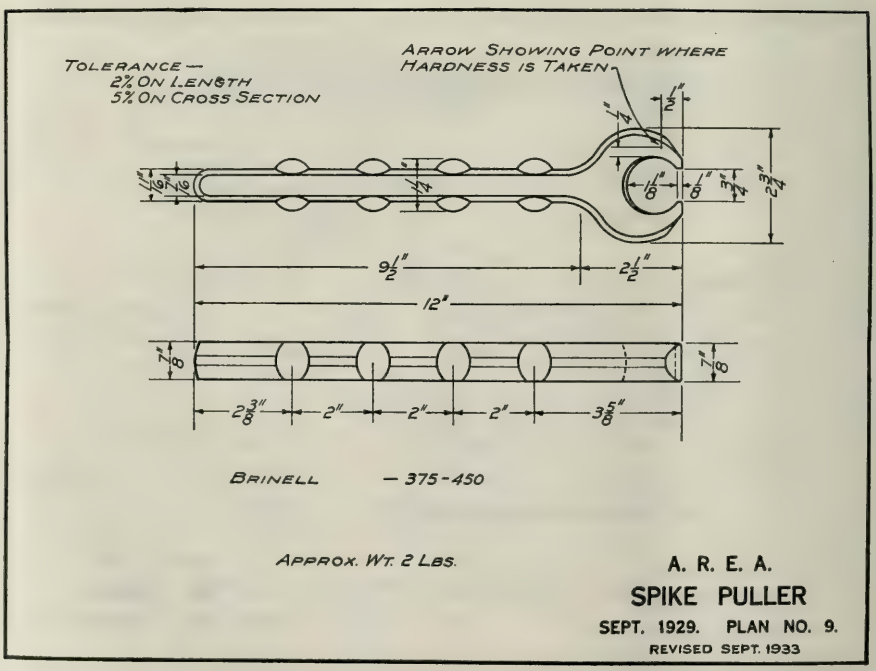


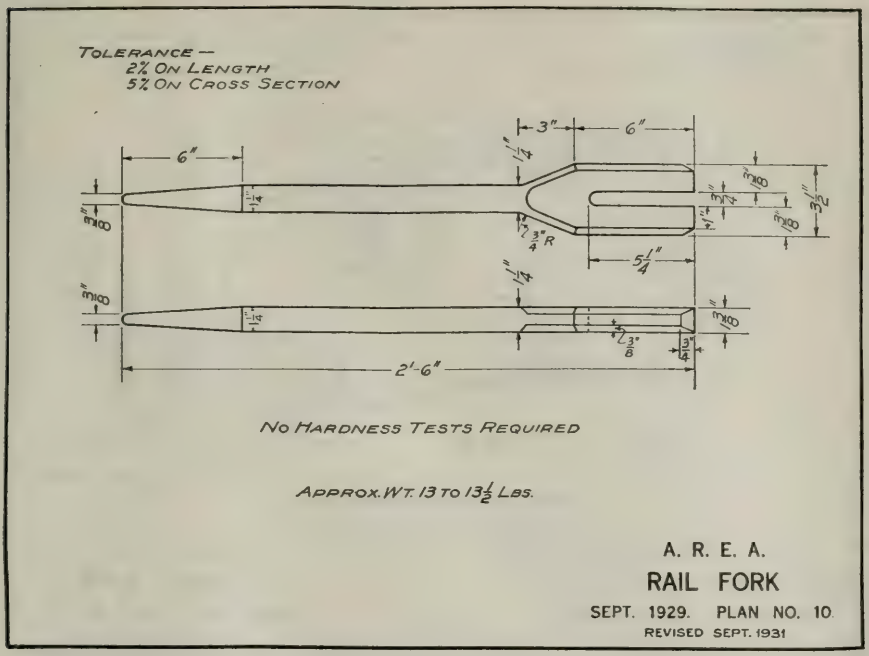
A. R. E. A.

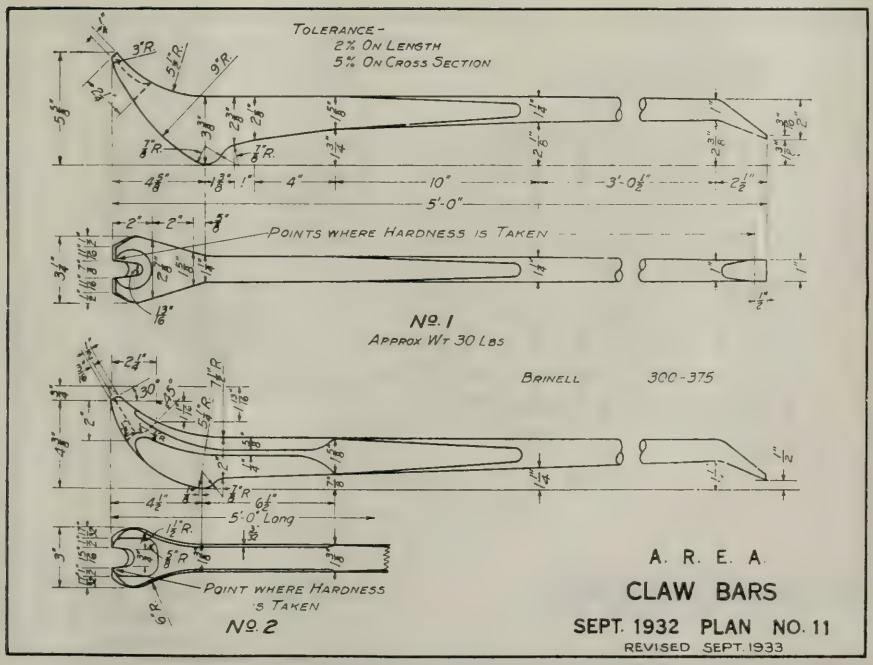
TIE TONGS

SEPT. 1929. PLAN NO. 7.


TOLERANCE —
2% ON LENGTH
5% ON CROSS SECTION
3'-8"
4"
1'-7"
5/8" RIVET
POINTS TO BE FINISHED BY GRINDING
9"
2'-7"
NO HARDNESS TESTS REQUIRED
APPROX. WT 17 LBS.
A. R. E. A.
TIMBER TONGS
SEPT. 1929. PLAN NO. 8
REVISED SEPT. 1931

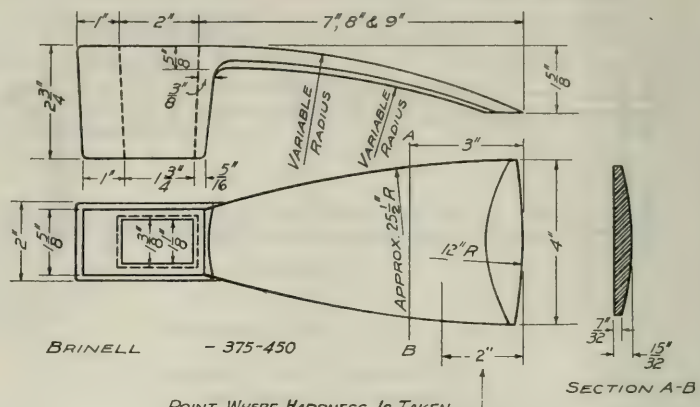

TOLERANCE —
2% ON LENGTH
5% ON CROSS SECTION
ARROW SHOWING POINT WHERE HARDNESS IS TAKEN
9 1/2"
2 1/2"
12"
2 3/8"
2"
2"
2"
3 5/8"
BRINELL — 375-450
APPROX. WT. 2 LBS.
A. R. E. A.
SPIKE PULLER
SEPT. 1929. PLAN NO. 9.
REVISED SEPT. 1933


TOLERANCE —
2% ON LENGTH
5% ON CROSS SECTION
NO HARDNESS TESTS REQUIRED
APPROX. WT. 13 TO 13½ LBS.
A. R. E. A.
RAIL FORK
SEPT. 1929. PLAN NO. 10
REVISED SEPT. 1931


TOLERANCE -
2% ON LENGTH
5% ON CROSS SECTION
POINTS WHERE HARDNESS IS TAKEN
No. 1
APPROX WT. 30 LBS
BRINELL 300-375
5'-0" Long
POINT WHERE HARDNESS IS TAKEN
No. 2
A. R. E. A.
CLAW BARS
SEPT. 1932 PLAN NO. 11
REVISED SEPT. 1933

TOLERANCE —
2% ON LENGTH
5% ON CROSS SECTION

NOTE:- FURNISHED IN OPEN HEARTH OR ALLOY STEEL AS SPECIFIED ON REQUISITION.



BRINELL — 375-450

POINT WHERE HARDNESS IS TAKEN

APPROX. WT { 7" - 5 LBS.
8" - 5 1/4 -
9" - 5 1/2 -

A. R. E. A.

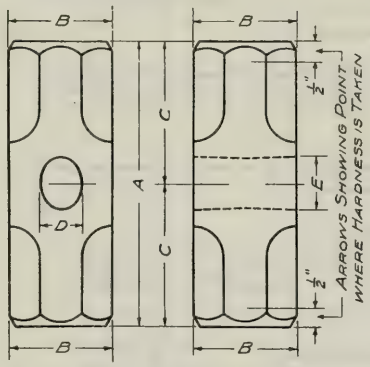
TRACK ADZE

SEPT. 1929. PLAN NO. 12

REVISED SEPT. 1933

TOLERANCE —
2% ON LENGTH
5% ON CROSS SECTION

NOTE:-FURNISHED IN OPEN HEARTH OR ALLOY STEEL AS SPECIFIED ON REQUISITION.



BRINELL — 425-500

SCHEDULE OF DIMENSIONS					
APPROX WT.	A	B	C	D	E
6 LB	6	2 1/8	3	1	1 1/4
8 "	6 1/2	2 1/4	3 1/4	1	1 1/4
10 "	7	2 1/2	3 1/2	1	1 3/8
12 "	7 1/2	2 5/8	3 3/4	1	1 3/8
14 "	8	2 3/4	4	1	1 3/8
16 "	8 1/4	2 7/8	4 1/8	1	1 3/8

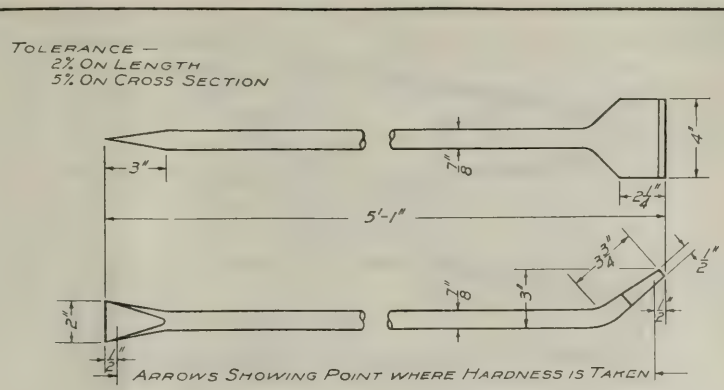
EYE TAPERED TO CENTER
4° ON LONG DIAMETER
3° ON SHORT DIAMETER

A. R. E. A.

DOUBLE FACED SLEDGE

SEPT 1929 PLAN NO 13.

REVISED SEPT 1933



BRINELL — 425-500

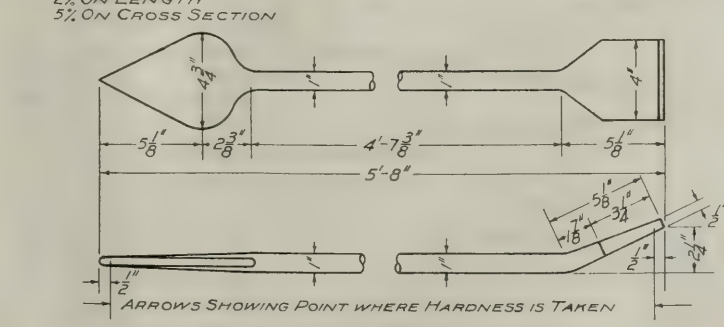
APPROX. WT. 13 LBS.

A. R. E. A.

CHISEL END TAMPING BAR

SEPT 1929. PLAN NO. 14.

REVISED SEPT. 1933



BRINELL — 425-500

APPROX. WT. 15 LBS.

A. R. E. A.

SPEAR END TAMPING BAR

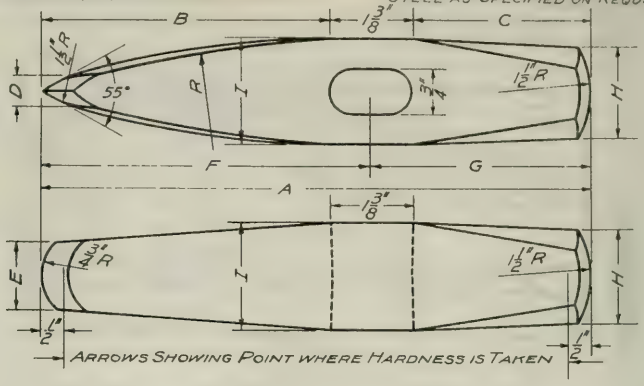
SEPT. 1929 PLAN NO. 15.

REVISED SEPT 1933

A

TOLERANCE -
2% ON LENGTH, 5% ON CROSS SECTION

NOTE:- FURNISHED IN OPEN HEARTH OR ALLOY STEEL AS SPECIFIED ON REQUISITION.



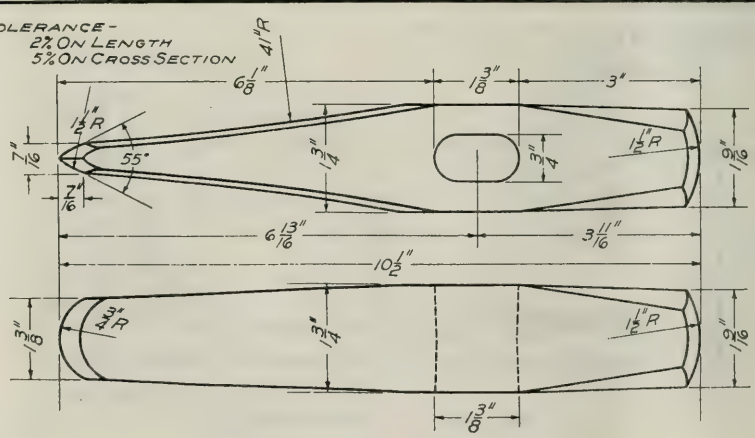
BRINELL { POINT - 477-532
HEAD - 286-340

APPROX. WT.	A	B	C	D	E	F	G	H	I	R
5 1/2 LBS.	9 1/4	4 7/8	3	7/16	1 1/8	5 9/16	3 11/16	1 9/16	1 3/4	18 7/8
6 1/2 LBS.	10 1/2	6 1/8	3	7/16	1 1/8	6 13/16	3 11/16	1 9/16	1 3/4	33 1/4

EYE TAPERED TO CENTER
4" ON LONG DIAMETER
3" ON SHORT DIAMETER

A. R. E. A.
TRACK CHISEL
DESIGN NO. 1.
SEPT 1929 PLAN NO. 16.
REVISED SEPT 1933

TOLERANCE -
2% ON LENGTH
5% ON CROSS SECTION

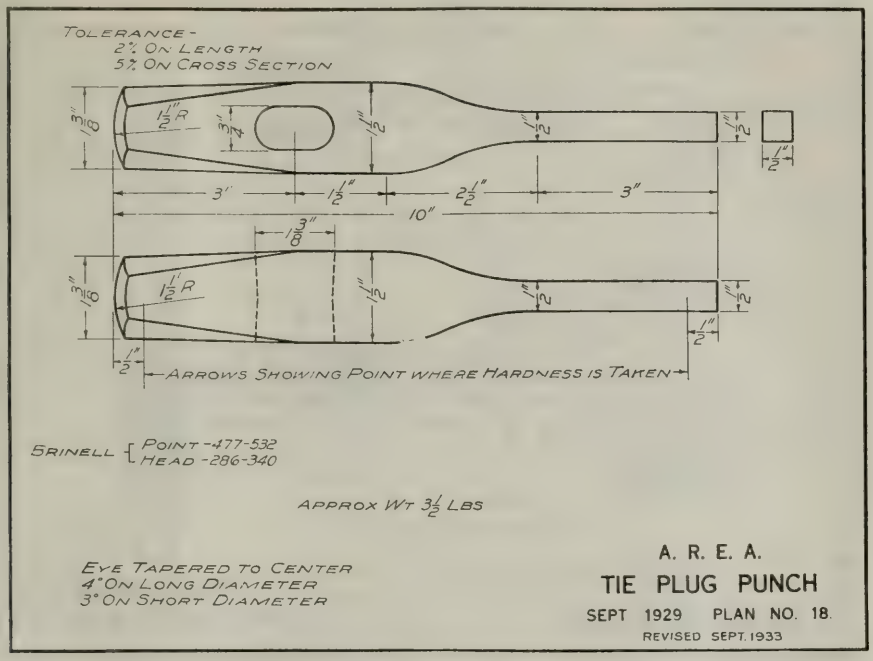


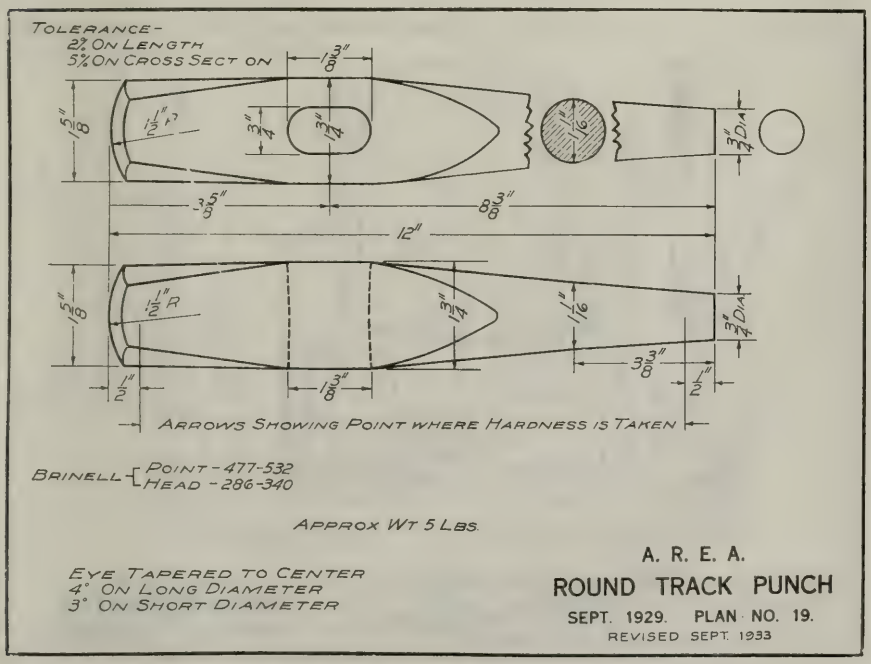
THIS DESIGN FURNISHED IN ALLOY STEEL ONLY

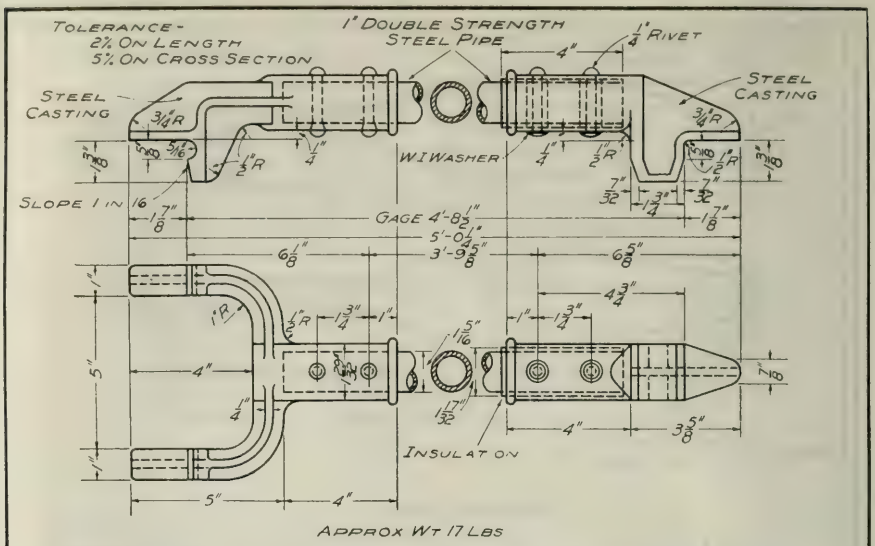
APPROX. WT 5 1/2 LBS

EYE TAPERED TO CENTER
4" ON LONG DIAMETER
3" ON SHORT DIAMETER

A. R. E. A.
TRACK CHISEL
DESIGN NO. 2.
SEPT. 1929 PLAN NO. 17.
REVISED SEPT. 1931

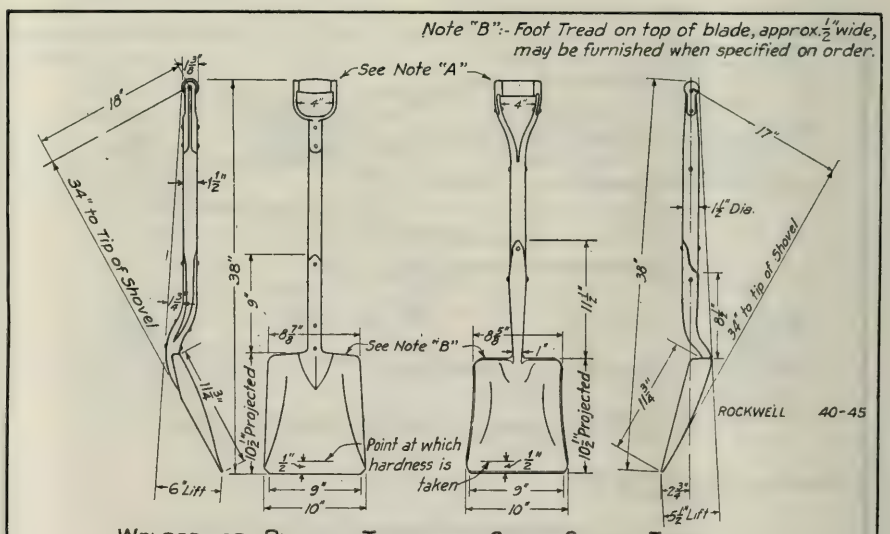

TOLERANCE-
2% ON LENGTH
5% ON CROSS SECTION
3/16"
1 1/2" R
3/4"
1 1/2"
1/2"
1/2"
1/2"
3"
1 1/2"
2 1/2"
3"
10"
1 3/8"
3/16"
1 1/2" R
1 1/2"
1/2"
1/2"
1/2"
1/2"
ARROWS SHOWING POINT WHERE HARDNESS IS TAKEN
BRINELL { POINT -477-532
HEAD -286-340
APPROX WT 3 1/2 LBS
EYE TAPERED TO CENTER
4" ON LONG DIAMETER
3" ON SHORT DIAMETER
A. R. E. A.
TIE PLUG PUNCH
SEPT 1929 PLAN NO. 18.
REVISED SEPT. 1933


TOLERANCE-
2% ON LENGTH
5% ON CROSS SECT ON
1 3/8"
5/8"
1 1/2" R
3/4"
3/4"
1/16
3/4" DIA
3 5/8"
8 3/8"
12"
5/8"
1 1/2" R
3/4"
1/16
3/4" DIA
3 3/8"
1/2"
1 3/8"
1/2"
ARROWS SHOWING POINT WHERE HARDNESS IS TAKEN
BRINELL { POINT -477-532
HEAD -286-340
APPROX WT 5 LBS.
EYE TAPERED TO CENTER
4" ON LONG DIAMETER
3" ON SHORT DIAMETER
A. R. E. A.
ROUND TRACK PUNCH
SEPT. 1929. PLAN NO. 19.
REVISED SEPT. 1933



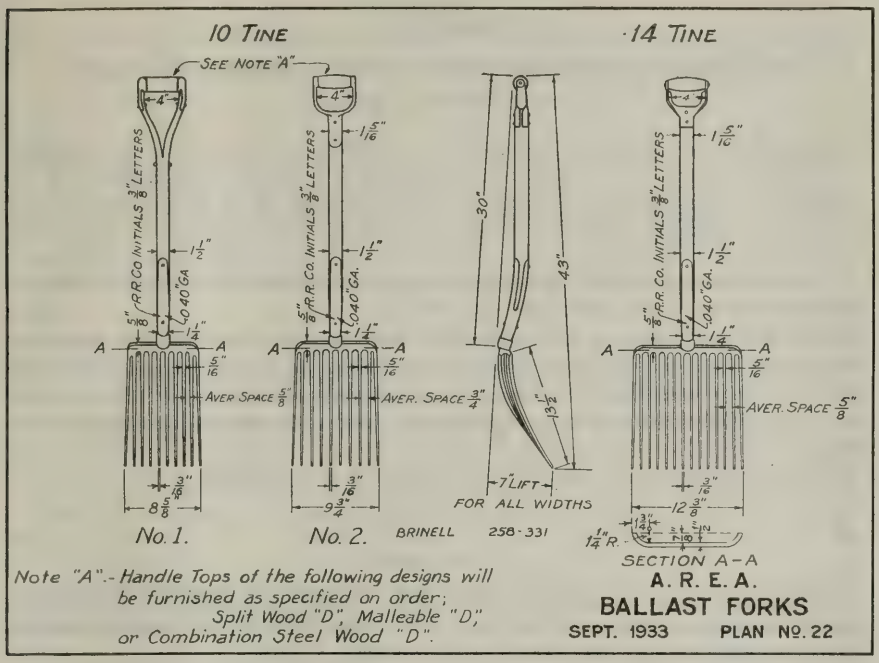
NOTES -
INSULATE BY USE OF FIBRE BUSHINGS AT BOTH ENDS WHEN REQUIRED
CENTER LINE TO BE MARKED ON GAGE WHEN REQUIRED
NO TOLERANCE ALLOWED IN GAGE DISTANCE

A. R. E. A.
TRACK GAGE
SEPT 1929 PLAN NO. 20.

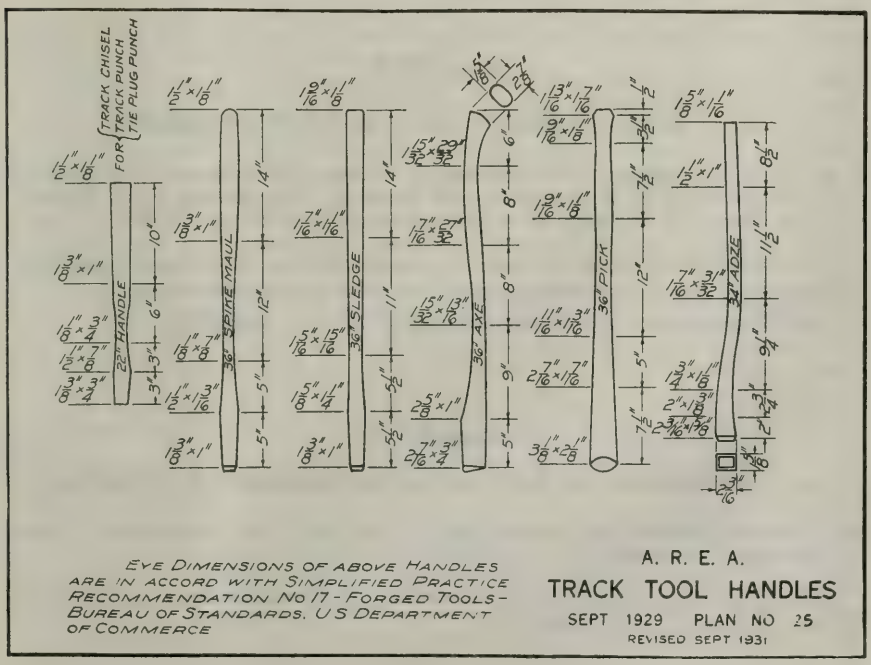


Note "A":- Handle Tops of the following designs will be furnished as specified on order; Split Wood "D", Malleable "D" or Combination Steel Wood "D"

A. R. E. A.
TRACK SHOVELS
SEPT. 1933 PLAN No. 21



Note "A".- Handle Tops of the following designs will be furnished as specified on order; Split Wood "D", Malleable "D", or Combination Steel Wood "D".



Appendix E

(4) PLANS FOR SWITCHES, FROGS, CROSSINGS, SLIP SWITCHES, ETC.

O. F. Harting, Chairman, Sub-Committee; C. A. Alden, E. W. Caruthers, J. W. DeMoyer, L. W. DesLauriers, J. A. Ellis, W. G. Hulbert, T. T. Irving, A. A. Johnson, F. H. Masters, J. V. Neubert, G. A. Peabody, O. C. Rehfuss, E. M. T. Ryder, G. J. Slibeck, G. L. G. Smith, H. C. Stiff, J. B. Strong, E. D. Swift, H. N. West, J. G. Wishart, M. J. T. Zeeman.

The plan presented in this Appendix was prepared in conference with the Standardization Committee of the Manganese Track Society.

The Committee presents for adoption as recommended practice Plan 505, which is a written plan consisting of specifications for adjustable guard rail clamps. Guard rail clamps are now in use on a number of large railroad systems, and this plan was prepared to enable railroads to obtain guard rail clamps of a more suitable and uniform design.

The Committee reports progress on a number of other assignments.

Conclusion

The Committee recommends that Plan 505—A.R.E.A. Specifications for Adjustable Guard Rail Clamps, included in the revised Portfolio of Trackwork Plans, be adopted as recommended practice and printed in the Manual.

Appendix F

(5) TRACK CONSTRUCTION IN PAVED STREETS

E. W. Caruthers, Chairman, Sub-Committee; C. A. Alden, W. G. Brown, J. E. Deckert, J. W. DeMoyer, F. W. Gardiner, C. R. Harding, O. F. Harting, W. G. Hulbert, W. A. Murray, J. B. Myers, G. A. Peabody, E. M. T. Ryder, H. C. Stiff.

The Committee confined its work this year to a review of its material appearing in the Manual, and revisions recommended have been handled under Appendix A.

The Committee reports progress on a number of other assignments.

Appendix G

(6) CORROSION OF RAIL AND FASTENINGS IN TUNNELS

W. H. Bettis, Chairman, Sub-Committee; C. J. Geyer, R. W. E. Bowler, J. de N. Macomb, J. V. Neubert, G. L. G. Smith, H. N. West.

The Committee reports progress. Information on this subject is not developed sufficiently to warrant a report this year.

Appendix H

(7) GAGE OF TRACK AND ELEVATION OF CURVES WITH REFERENCE TO THE USE OF ROLLER BEARINGS ON RAILROAD EQUIPMENT

C. W. Breed, Chairman, Sub-Committee; J. E. Hogan, C. M. McVay, C. R. Strattman, T. P. Warren.

The elevation of curves must be governed primarily by the speed of trains passing over them. If the use of roller bearings because of mechanical construction were a controlling factor of the speed of trains in which they might be used, to that extent might they be an element in selecting the proper elevations of curves over which the train passed.

In order to obtain accurate information relative to the possible limits in the use of roller bearings on curves at any desired speed of operation, letters of inquiry were addressed to the large manufacturers of roller bearings which elicited the following replies:

Fafnir Bearings Incorporated, New Britain, Connecticut.—"We have been over this subject carefully with our engineering department, and beg to advise that the problem, as far as it relates to the use of our roller bearings, the same standards would apply as on the sleeve bearings. In other words, we do not make a rigid set up as is common in some types on the market. Our application carries the same float as is common with sleeve type bearings, and the same clearance between the end of the axle and the thrust block."

Hyatt Bearing Division, General Motors Corporation, Newark, New Jersey.—"From the standpoint of Hyatt roller bearing applications to rolling stock, we do not see that there are any problems involved with a Hyatt application which are not present with the brass bearing application. The Hyatt type axle is allowed a lateral freedom similar to that allowed with the brass bearing axle. The total lateral clearance for a Hyatt axle is from 3/8 in. to 1/2 in. which will compare with a similar clearance for a new installation of brass bearings. We are, therefore, of the opinion that any standards, which are affecting track elevation and gage, will be equally applicable to either brass bearings or Hyatt roller bearing journals."

Shafer Bearing Corporation, 6501–99 W. Grand Ave., Chicago.—"With Shafer roller bearing used in railroad equipment, fitted in American Steel Foundry units, we are glad to advise that in these units the axle shaft is stationary and is carried in regular journal boxes, with no change in lateral clearance. For this reason their action on curves will be identically the same as the standard plain bearings."

S K F Industries, Inc., 40 East 34th Street, New York.—"We have been using the S K F Spherical Roller Bearing for journal applications for more than ten years and have had extensive experience with practically all types of steam railway equipment except freight cars. We have done some work with freight cars, but very little in comparison to that represented by the use of these bearings on passenger train equipment and locomotives. The questions raised in your letter are not the ones which we have had occasion to study or investigate thoroughly. Up to the present time, we have seen nothing to indicate that any special requirements for gage of track or elevation of the outer rail on curves are necessary when the spherical journal bearing is used."

The Timken Roller Bearing Company, Canton, Ohio.—"On the subject of track gage and elevation of curves, we are of the opinion that no changes should be made in the tables because of roller bearings. Any new conditions, which may arise from the use of roller bearings, should properly be confined to the rolling stock so equipped. The formula for elevation of the outer rail on a curve is a function of speed and degree of curvature only. The condition of rolling stock does not enter in except as it may affect speed. We have noted a marked tendency to introduce roller bearings on high-speed equipment. As the modern trend is toward higher speeds, some changes in track may be made, but no changes in the tables are involved. Regarding lateral play at journal boxes, we have found it possible to obtain any desired amount of movement between box and frame as designed for Timken bearings. Wheel gages can also be varied. These possibilities are fortunate, as the table for gages and flangeways always contains a large number of factors and should not be made more complicated."

Conclusion

There is no different problem in the selection of the proper elevation for curves over which it is desired to operate railway equipment using roller bearings than is present if equipment is supplied with ordinary bearings.

This report is submitted as information.

Appendix I

(8) EFFECT OF EXISTING MATERIALS IN TRACK ON DESIGN OF TIE PLATES AND PUNCHING THEREOF, TOGETHER WITH INTERRELATION OF SLOTTING OF JOINT BARS AND SIZE OF TRACK SPIKES

J. de N. Macomb, Chairman, Sub-Committee; W. H. B. Bevan, R. W. E. Bowler, H. R. Clarke, L. W. Deslauriers, F. W. Gardiner, C. R. Strattman.

On account of the preparation of designs for Tie Plates by the Track Committee and for Joint Bars by the Rail Committee, it is recommended that this subject be discontinued.

Appendix I–1

(8–A) DESIGN OF TIE PLATES FOR RE RAIL SECTIONS

J. de N. Macomb, Chairman, Sub-Committee; W. G. Arn, W. H. Bettis, W. H. B. Bevan, M. D. Bowen, R. W. E. Bowler, E. W. Caruthers, H. R. Clarke, L. W. Deslauriers, J. A. Ellis, F. W. Gardiner, C. J. Geyer, C. R. Harding, F. W. Hillman, A. A. Johnson, J. B. Myers, J. V. Neubert, E. M. T. Ryder, J. R. Scatterday, G. L. G. Smith, G. M. Strachan, C. R. Strattman, J. R. Watt, J. G. Wishart.

At the meeting of the Track Committee on September 21, 1933, the subject "Plans for Standard Tie Plates" was assigned.

Standard drawings of most of the larger railroads represented in the Association covering track materials were available to the Sub-Committee. From these standard drawings tabulations were prepared, showing the characteristics of the tie plates in use by these railroads with rails of various weights and sections. Studies were made of these tabulations, keeping in mind the trend toward more sturdy construction in railroad track, as a result of which the tie plate plans shown in Fig. 2 to 8, inclusive, were prepared, their principal characteristics and uses being summarized in Fig. 1.

Fig. 1 to 8 inclusive, attached hereto, together with the two "Notes", 1 and 2, are presented for adoption as recommended practice.

Conclusions

The Committee recommends:

That the material shown under the headings "Table of Dimensions for Tie Plates" and "Data for Designing Tie Plates" on page 251 of the 1929 Manual be withdrawn.

That plans, Fig. 1 to 8, inclusive, submitted herewith, together with Notes 1 and 2, following, be adopted as recommended practice and printed in the Manual.

Note 1.—Where a railroad's existing Standard Tie Plate is canted approximately 1 in 20, or has no cant (flat), A.R.E.A. standard design may be modified to correspond therewith, for use with rails having the same base width.

Note 2.—Where existing standard spacing of spike holes, parallel to shoulder of tie plate, used with same width of rail base by any railroad, is not in accordance with A.R.E.A. standard, such existing spacing may be substituted.

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CHARACTERISTICS	LENGTH OF TIE PLATE			
	10 INCH	11 INCH	12 INCH	14 INCH
RAIL (Weight-section & base width)	90 lb.-R.A.-5⅛ in.			
ENDS-PROVISION FOR ATTACHING TO TIE	Inclined			
SHOULDERS (Number of)	One			
CAMBER OR CROWN	None or Pressed; Rolled			
BOTTOM FORMATION	None (Flat); 2 Transverse Ribs; Anchor; None (Flat); 2 Transverse Ribs; Anchor			
REFERENCE (Fig. number)	Fig. 2			
RAIL (Weight-section & base width)		100 lb-R.E.-5⅜ in. & 100 lb-R.A.-5½ in		
ENDS-PROVISION FOR ATTACHING TO TIE		Inclined-For cut spikes		
SHOULDERS (Number of)		One; Two		
CAMBER OR CROWN		None or Pressed; Rolled; None or Pressed; Rolled		
BOTTOM FORMATION		None (Flat); 2 Transverse Ribs; Anchor; None (Flat); 2 Transverse Ribs; Anchor; None (Flat); 2 Transverse Ribs; Anchor; None (Flat); 2 Transverse Ribs; Anchor		
REFERENCE (Fig. number)		Fig. 3; Fig. 4		
RAIL (Weight-section & base width)		112 lb-RE & 110 lb RE-5½ in		
ENDS-PROVISION FOR ATTACHING TO TIE		Inclined-For cut spikes	Flat-For screw spikes	
SHOULDERS (Number of)		One; Two	Two	
CAMBER OR CROWN		None or Pressed; Rolled; None or Pressed; Rolled	Rolled	
BOTTOM FORMATION		None (Flat); 2 Transverse Ribs; Anchor; None (Flat); 2 Transverse Ribs; Anchor; None (Flat); 2 Transverse Ribs; Anchor; None (Flat); 2 Transverse Ribs; Anchor	None (Flat)	
REFERENCE (Fig number)		Fig. 3; Fig. 4	Fig. 5	
RAIL (Weight-section & base width)			131 lb-R.E. & 130 lb-R.E.-6 in.	
ENDS-PROVISION FOR ATTACHING TO TIE			Inclined-For cut spikes	Flat-For screw spikes
SHOULDERS (Number of)			One; Two	Two
CAMBER OR CROWN			None or Pressed; Rolled; None or Pressed; Rolled	Rolled
BOTTOM FORMATION			None (Flat); 2 Transverse Ribs; Anchor; None (Flat); 2 Transverse Ribs; Anchor; None (Flat); 2 Transverse Ribs; Anchor; None (Flat); 2 Transverse Ribs; Anchor	None (Flat)
REFERENCE (Fig number)			Fig. 6; Fig. 7	Fig. 8

All A.R.E.A. Standard Tie Plates to be 7½ inches wide.

Where existing standard spacing of spike holes, parallel to shoulder of tie plate, used with same width of rail base by any railroad, is not in accordance with A.R.E.A. standard, such existing spacing may be substituted.

All A.R.E.A. Standard Tie Plates to be canted approximately 1 in 40.

Where a railroad's existing Standard Tie Plate is canted approximately 1 in 20, or has no cant (Flat), A.R.E.A. standard design may be modified to correspond therewith, for use with rails having the same base width.

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FIG. 1 — CHARACTERISTICS OF TIE PLATES

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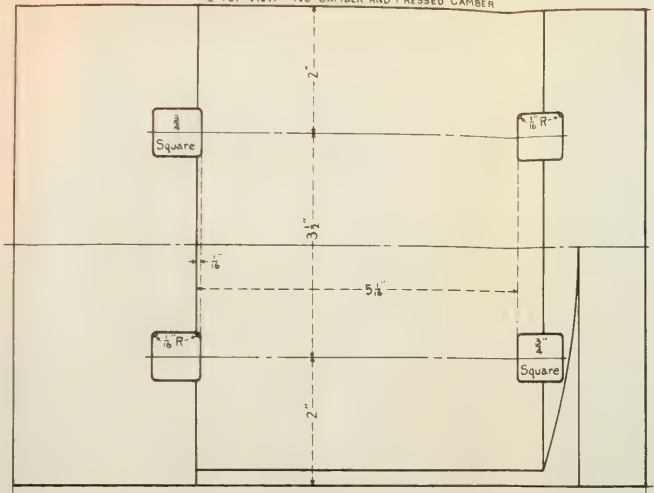
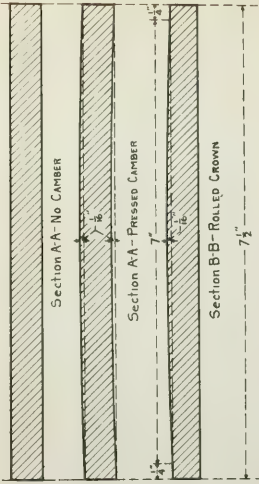
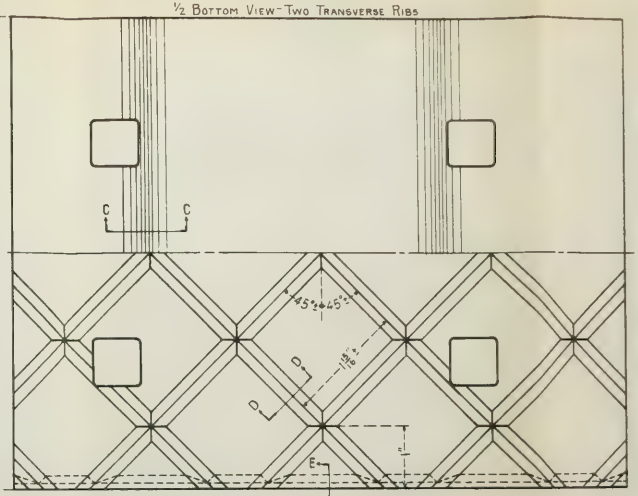
½ Top View – No Camber and Pressed Camber

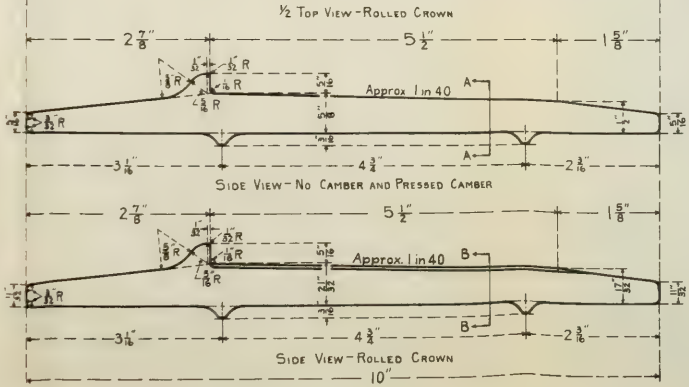




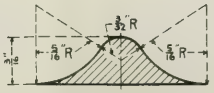
½ Bottom View – Two Transverse Ribs



½ Top View – Rolled Crown

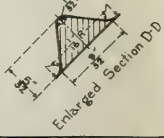


½ Bottom View – Anchor Bottom



Enlarged Section C-C

Enlarged Section E-E



Enlarged Section D-D

Estimated Weights									
Characteristics		No Camber and Pressed Camber				Rolled Crown			
		Thickness	Per Foot	Per 7½ Inch	Per Finished Tie Plate	Per Foot	Per 7½ Inch	Per Finished Tie Plate	Thickness
Bottom Formation	None (Flat)	5/8	17.71	11.07	10.68	18.29	11.43	11.03	21/32
	2 Transverse Ribs	5/8	18.05	11.28	10.88	18.62	11.64	11.24	21/32
	Anchor	5/8	18.37	‡ 11.48	‡ 11.08	18.94	‡ 11.84	‡ 11.43	21/32
*		1/16	2.125	1.328	1.288	2.125	1.328	1.288	1/16

* Difference in estimated weights due to difference in thicknesses of 1/16 inch.
‡ When side ribs are used with Anchor bottom add 0.07 lb. to weights shown

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Fig. 2 – A.R.E.A. – 10 Inch Tie Plate – Inclined Ends – Single Shoulder

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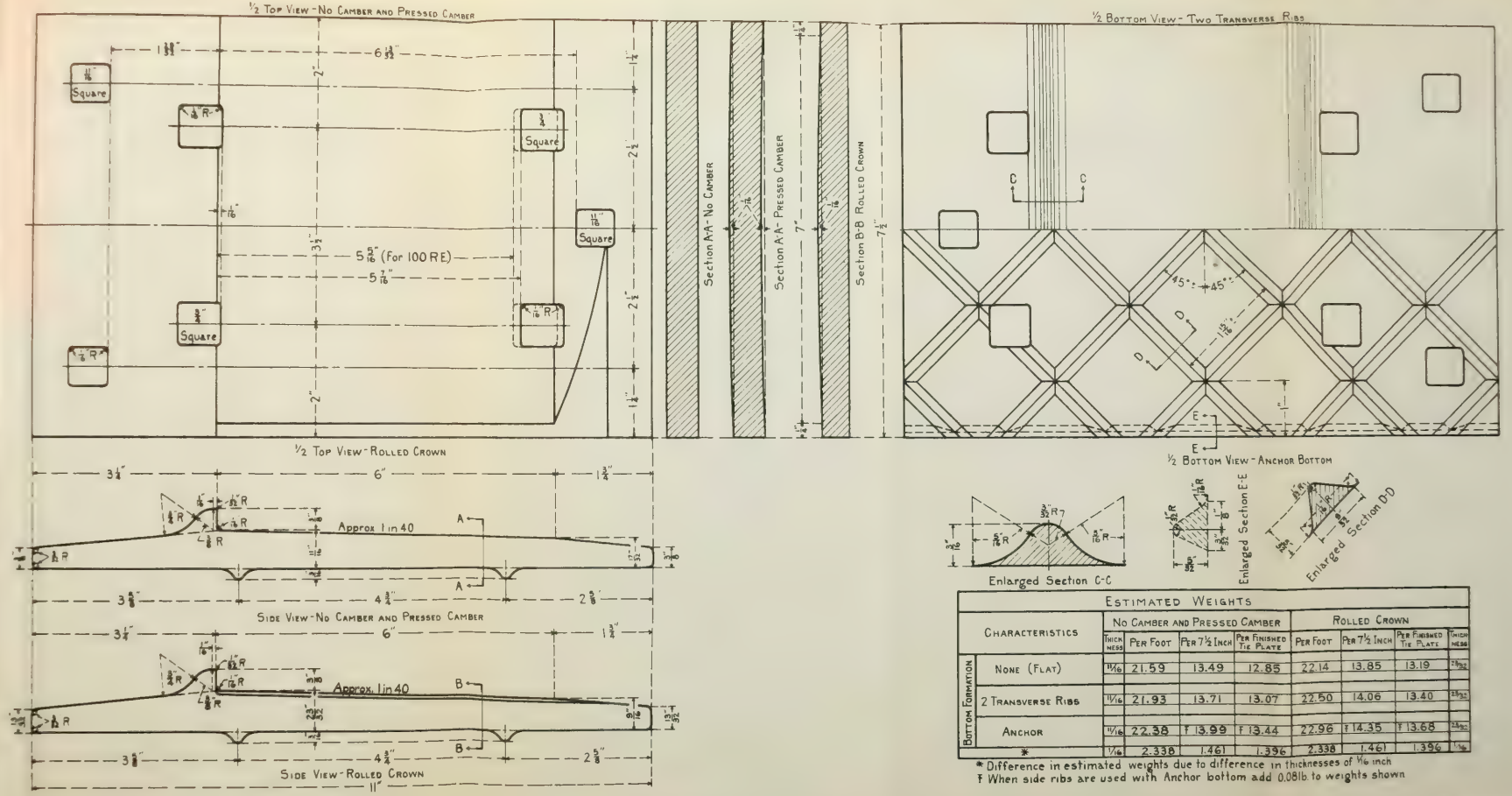

Estimated Weights									
Characteristics		No Camber and Pressed Camber				Rolled Crown			
		Thickness	Per Foot	Per 7½ Inch	Per Finished Tie Plate	Per Foot	Per 7½ Inch	Per Finished Tie Plate	Thickness
Bottom Formation	None (Flat)	11/16	21.59	13.49	12.85	22.14	13.85	13.19	23/32
	2 Transverse Ribs	11/16	21.93	13.71	13.07	22.50	14.06	13.40	23/32
	Anchor	11/16	22.38	† 13.99	† 13.44	22.96	† 14.35	† 13.68	23/32
	*	1/16	2.338	1.461	1.396	2.338	1.461	1.396	1/16

* Difference in estimated weights due to difference in thicknesses of 1/16 inch
† When side ribs are used with Anchor bottom add 0.08 lb. to weights shown

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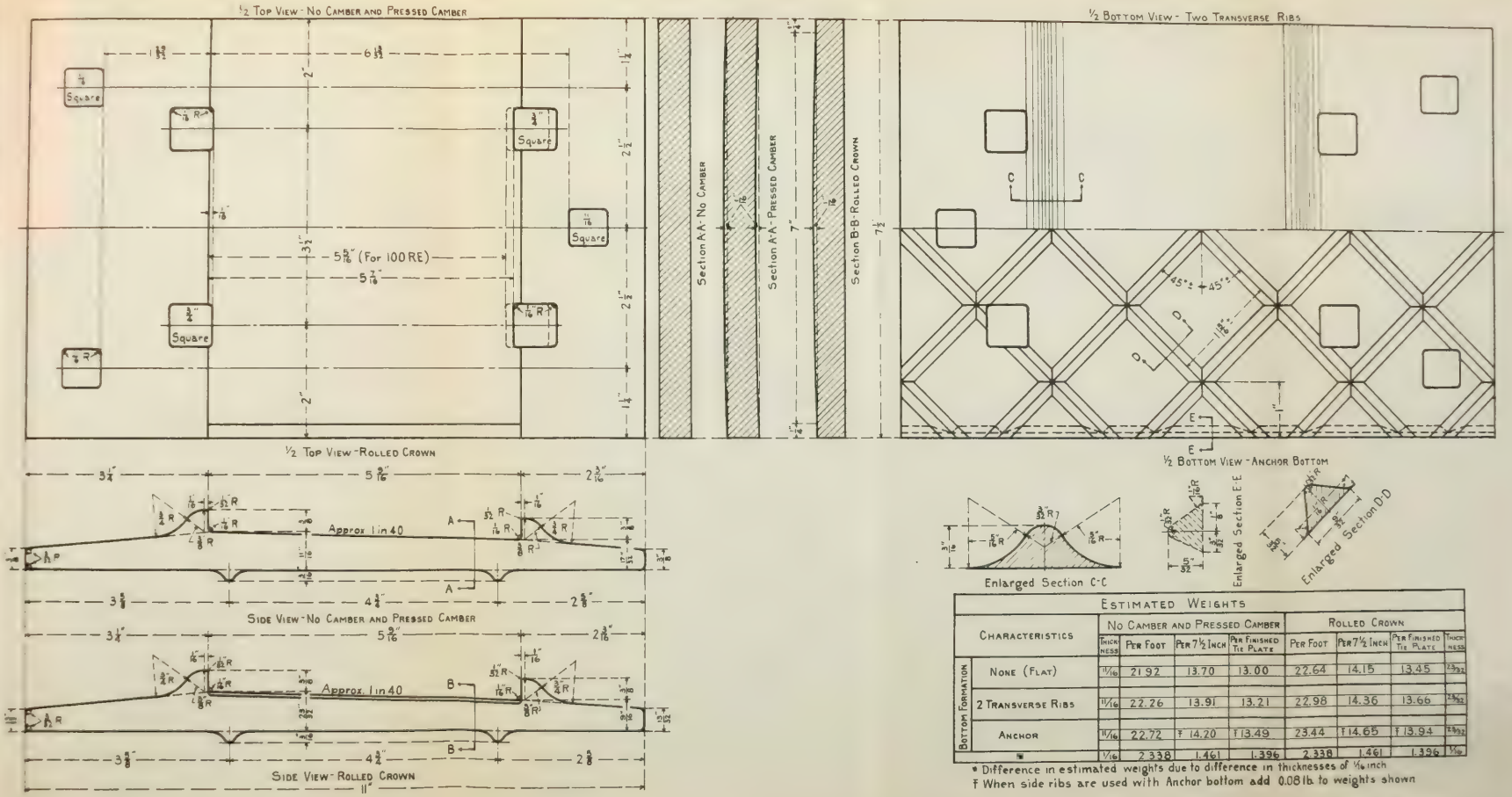
Fig. 3 - A.R.E.A. - 11 Inch Tie Plate - Inclined Ends - Single Shoulder

Revised



Estimated Weights									
Characteristics		No Camber and Pressed Camber				Rolled Crown			
		Thickness	Per Foot	Per 7½ Inch	Per Finished Tie Plate	Per Foot	Per 7½ Inch	Per Finished Tie Plate	Thickness
Bottom Formation	None (Flat)	11/16	21.92	13.70	13.00	22.64	14.15	13.45	23/32
	2 Transverse Ribs	11/16	22.26	13.91	13.21	22.98	14.36	13.66	23/32
	Anchor	11/16	22.72	‡ 14.20	‡ 13.49	23.44	‡ 14.65	‡ 13.94	23/32
*		1/16	2.338	1.461	1.396	2.338	1.461	1.396	1/16

* Difference in estimated weights due to difference in thicknesses of 1/16 inch.

‡ When side ribs are used with Anchor bottom add 0.08 lb. to weights shown

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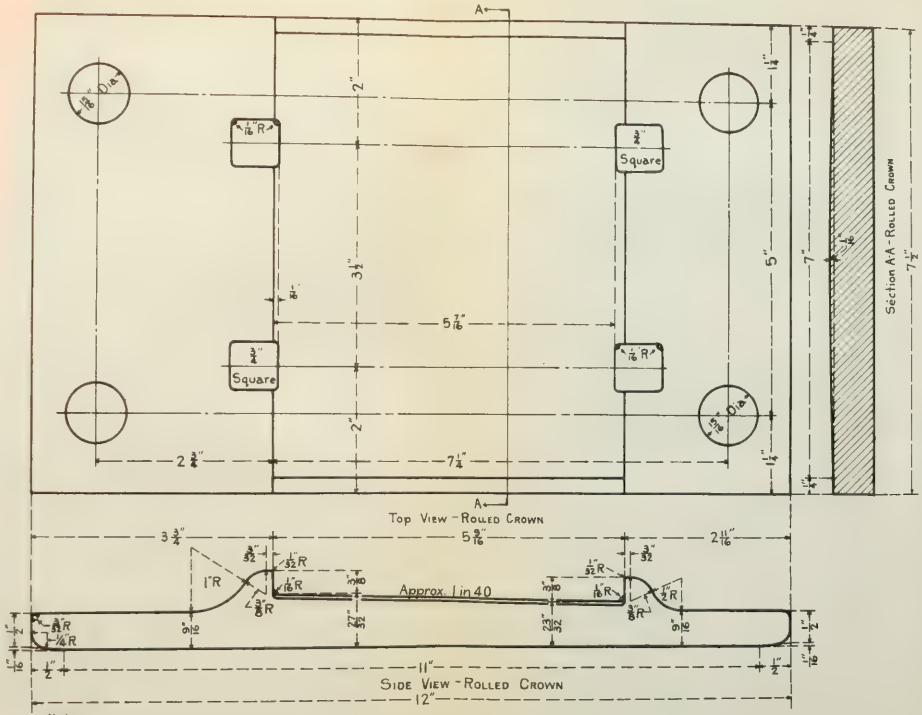
Fig. 4 - A.R.E.A. - 11 Inch Tie Plate - Inclined Ends - Double Shoulder

Revised Fe



Note:-
When rolled at right angles to direction of shoulders, low shoulder may be omitted.

Estimated Weights					
Characteristics		Thickness	Rolled Crown		
			Per Foot	Per 7½ Inch	Per Finished Tie Plate
Bottom Tabulation	None (Flat)	27/32	28.56	17.85	16.80
*		1/16	2.550	1.594	1.506

*Difference in estimated weights due to difference in thicknesses of 1/16 inch

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Fig 5 - A.R.E.A. - 12 Inch Tie Plate - Flat Ends - Double Shoulder

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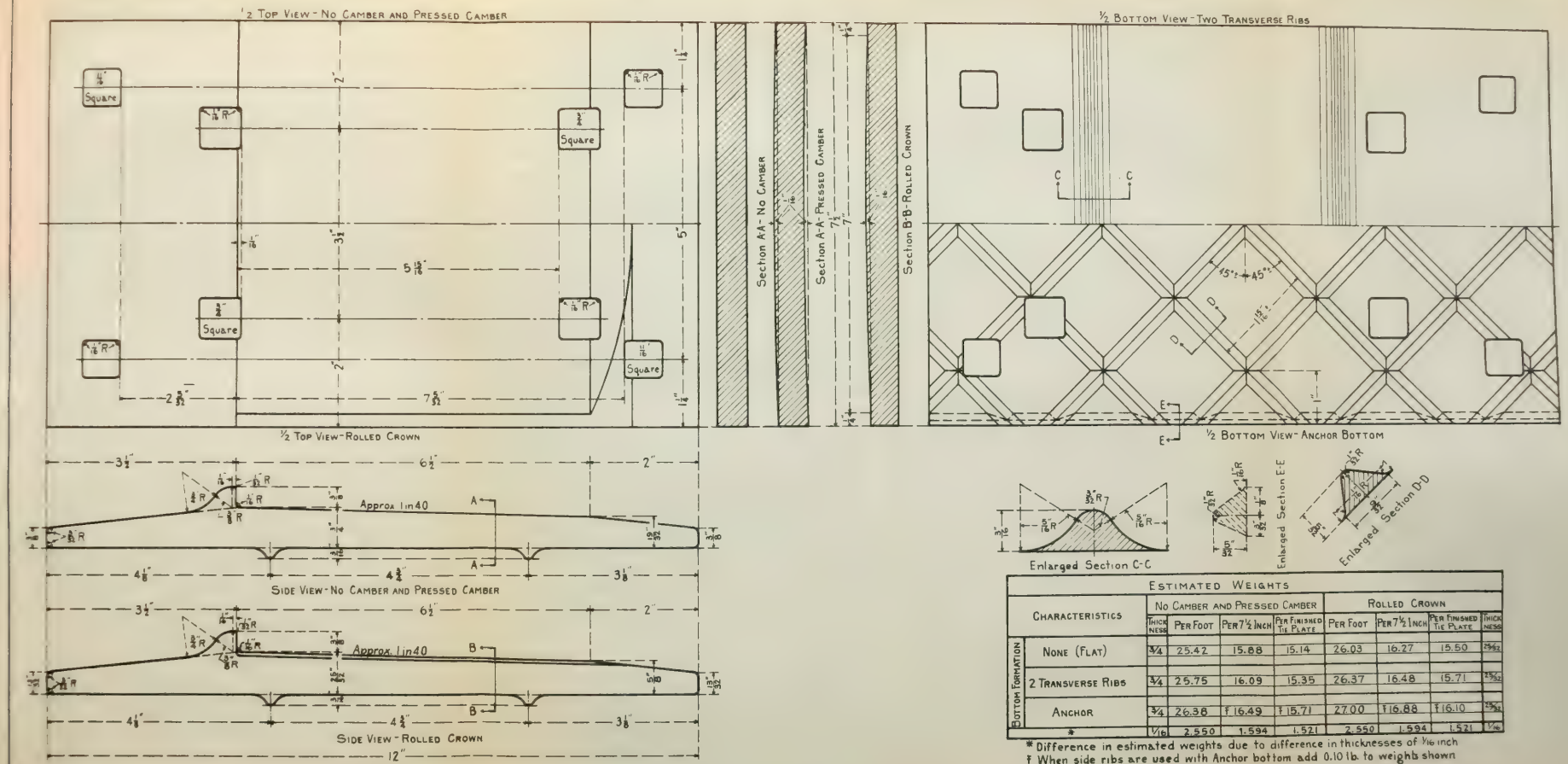

Estimated Weights								
Characteristics		No Camber and Pressed Camber				Rolled Crown			
		Thickness	Per Foot	Per 7½ Inch	Per Finished Tie Plate	Per Foot	Per 7½ Inch	Per Finished Tie Plate	Thickness
Bottom Formation	None (Flat)	¾	25.42	15.88	15.14	26.03	16.27	15.50	25/32
	2 Transverse Ribs	¾	25.75	16.09	15.35	26.37	16.48	15.71	25/32
	Anchor	¾	26.38	† 16.49	† 15.71	27.00	† 16.88	† 16.10	25/32
	*	1/16	2.550	1.594	1.521	2.550	1.594	1.521	1/16

* Difference in estimated weights due to difference in thicknesses of 1/16 inch
† When side ribs are used with Anchor bottom add 0.10 lb. to weights shown

Revised February 28, 1934

Fig 6 - A.R.E.A. - 12 Inch Tie Plate - Inclined Ends - Single Shoulder

$\frac{1}{16}''$ $5\frac{1}{8}''$

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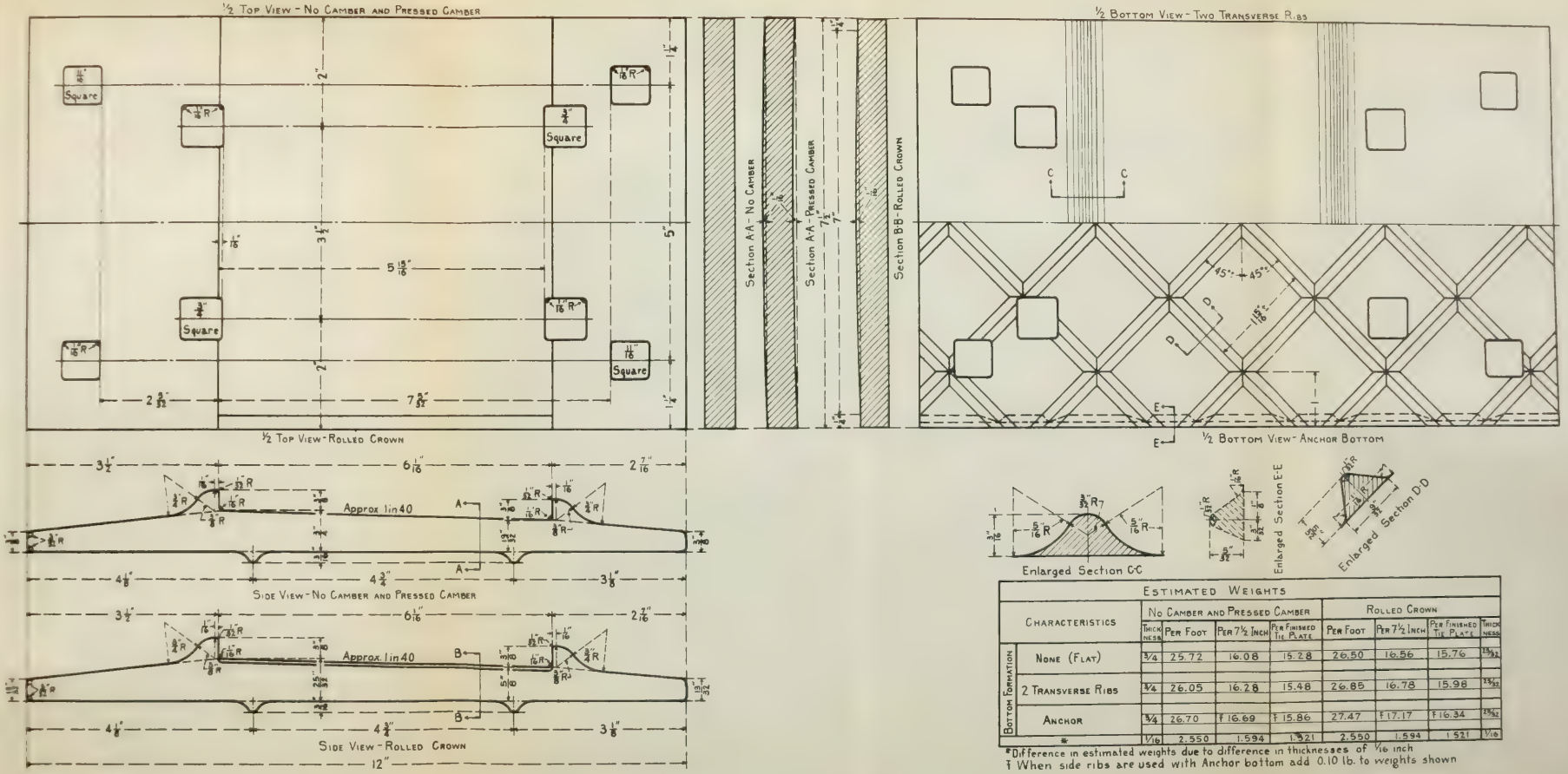


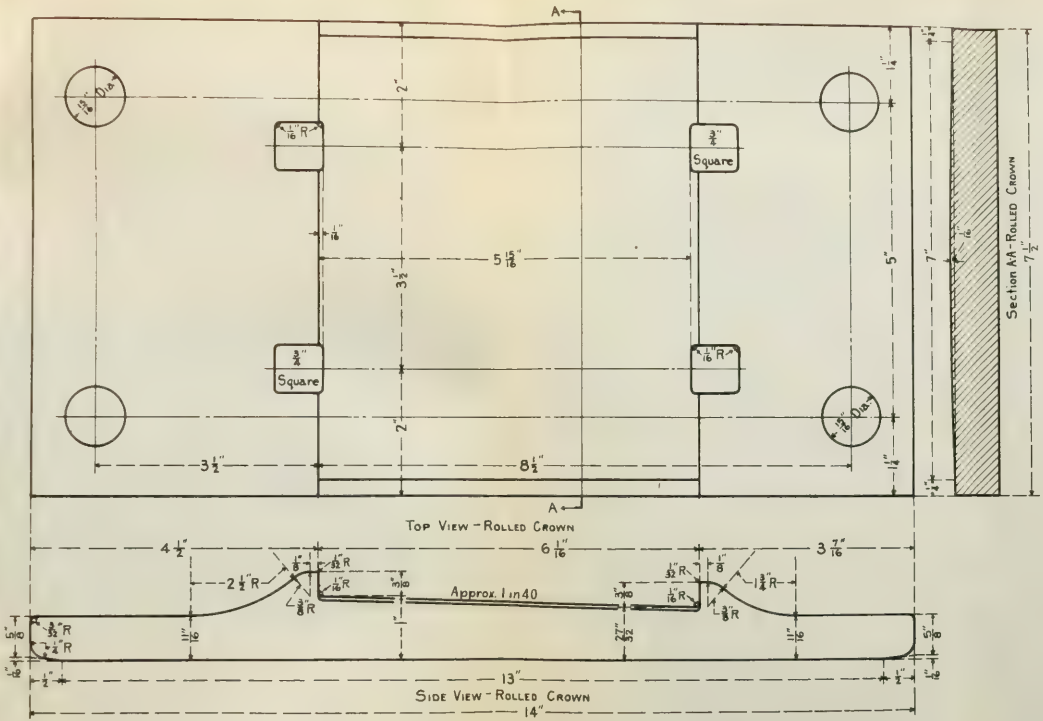
Estimated Weights										
Characteristics		No Camber and Pressed Camber				Rolled Crown				
		Thickness	Per Foot	Per 7½ Inch	Per Finished Tie Plate	Per Foot	Per 7½ Inch	Per Finished Tie Plate	Thickness
Bottom Formation	None (Flat)	¾	25.72	16.08	15.28	26.50	16.56	15.76	13/32
	2 Transverse Ribs	¾	26.05	16.28	15.48	26.85	16.78	15.98	13/32
	Anchor	¾	26.70	† 16.69	† 15.86	27.47	† 17.17	† 16.34	13/32
	*	1/16	2.550	1.594	1.521	2.550	1.594	1.521	1/16

*Difference in estimated weights due to difference in thicknesses of 1/16 inch
† When side ribs are used with Anchor bottom add 0.10 lb. to weights shown

Revised February 28, 1934

Fig. 7 - A.R.E.A. - 12 Inch Tie Plate - Inclined Ends - Double Shoulder

Revised



Estimated Weights				
Characteristics		Thickness	Rolled Crown	
			Per Foot	Per 7½ Inch	Per Finished Tie Plate
Bottom Formation	None (Flat)	1	39.91	24.94	23.67
*		1/16	2.980	1.862	1.813

*Difference in estimated weights due to difference in thicknesses of 1/16 inch

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Fig. 8 - A.R.E.A. - 14 Inch Tie Plate - Flat Ends - Double Shoulder

* * * * * *

On account of the urgent need for the tie plate standards due particularly to the recent adoption of new rail sections, the Track Committee is submitting these plans for adoption as recommended practice rather than as information. With this in view, the Committee will welcome suggestions and criticisms.

Appendix J

(9) PRACTICABILITY OF USING REFLEX UNITS FOR SWITCH LAMPS AND TARGETS

J. B. Myers, Chairman, Sub-Committee; W. H. Bettis, J. J. Desmond, F. J. Jerome, H. D. Knecht, J. C. Mock, J. B. Strong.

The subject this year was a reassignment from the previous year, and it was thought that information would be available from which definite recommendations could be made. In the 1932 report, twenty railroads had a limited number of Reflex Units in test, and three had an appreciable number in service and considered them satisfactory.

Our investigation this year develops the fact that many of the roads who reported in 1932 as having Reflex Units in test, have removed them, account of discontinuing the use of Switch Lamps in the Automatic Signal territory.

A few of the roads report that they are continuing their tests, but have no information to report this year.

Two roads reported they had installed additional units for test. The two roads who have a large number in service and who appear to have standardized on the Reflex Unit, report they expect to continue replacing lighted switch lamps with the Reflex Lens as rapidly as conditions permit.

None of the roads questioned has considered the use of reflex units outlining the banner or target of switch stands, thereby eliminating the switch lamp or its substitute.

Conclusion

Recommend that this report be received as information.

Appendix K

(10) SELECTIVE WELDING UP AT JOINTS, INSTEAD OF WELDING OUT OF FACE

F. W. Hillman, Chairman, Sub-Committee; W. G. Arn, M. D. Bowen, J. A. Ellis, C. J. Rist, G. L. Sitton.

Subject No. 13 added to Track Committee's work precludes investigation of subjects suggested in conclusion of report of Sub-Committee 10 appearing on page 518 of Vol. 34, 1933 Proceedings, and limits investigation of this Committee to determining when selective or out of face welding shall be done. This phase was completely reported on last year. Therefore it is now the recommendation of Sub-Committee 10 that report appearing on page 515, Vol. 34 of 1933 Proceedings be accepted as information and subject dropped until some future date when greater progress in welding of rail at joints has been made and developments warrant further study of the subjects.

Appendix L

(11) DESIRABLE TIGHTNESS OF TRACK JOINTS AND EFFECT UPON THE LIFE OF RAILS AND JOINTS OF OVERTIGHT JOINTS; OF LOOSE JOINTS

W. J. Harris, Chairman, Sub-Committee; J. J. Desmond, J. de N. Macomb, I. H. Schram, Theo. Speiden Jr., T. P. Warren, M. J. T. Zeeman.

The following questionnaire was sent to all railroads represented in the A.R.E.A. to ascertain their practice, experience and opinions on this subject.

1. What is "desirable tightness" of track joints to obtain maximum life of rail and joints?
2. How do you determine "desirable tightness" of track joints?
3. What effect has overtight joints on rail, such as:
   (a) Battered ends?
   (b) Wear on fishing surfaces?
   (c) Breakage through bolt holes, etc.?
4. What effect have loose joints on rail, such as:
   (a) Battered ends?
   (b) Wear of fishing surfaces?
   (c) Breakage through bolt holes, etc.?
5. To what extent is the life of rail shortened by:
   (a) Overtight joints?
   (b) Loose joints?
6. To what extent is the life of joints shortened by:
   (a) Overtight joints?
   (b) Loose joints?
7. Does the use of spring washers or joint springs have any effect on overtightening?

Answers were received from thirty-five railroads. These answers are such that a brief summary cannot be made and a complete copy of them would be quite voluminous.

Opinions given for "desirable tightness" vary from 7,000 lb. to 20,000 lb. per bolt.

The majority opinion, however, as given in the answers to the questionnaire is summarized in the following:

Conclusions

1. Desirable Tightness of Track Joints

Desirable tightness of track joints is that degree of tightness in which the bolts are kept as tight as possible, and still permit the rails to move uniformly with contraction and expansion. This can be obtained by the average trackman exerting his full strength on a forty-two to a forty-eight inch wrench, depending on the size of bolt, kind of threads and condition of bolt, and by frequent inspection and careful maintenance.

2. Effect Upon the Life of Rails and Joints of Overtight Joints

With overtight joints there is a tendency for rails to kink and for batter to be excessive at the wider joint openings, due to distribution of expansion not being uniform. This, however, will have little effect generally upon the life of the rail as a whole. The life of the joints will be increased because the tightness will tend to reduce to a minimum the movement of rails and joint assembly, thereby reducing wear.

3. Effect Upon the Life of Rails and Joints of Loose Joints

Loose joints cause excessive batter of rail ends; cause surface bent rails; cause abnormal wear on both rails and joints, thereby materially shortening the life of both; and are responsible for a very large portion of the labor cost of maintenance.

The Committee offers this report as information and recommends that the subject be discontinued.

Recapitulation of Answers Received from A.R.E.A. Questionnaire

Committee V-Track - Sub-Committee 13.

Recapitulation of Answers Received from A.R.E.A. Questionnaire

Committee V-Track - Sub-Committee 13.

Railroads	QUESTION 1. What year did you commence building up rail ends?		QUESTION 2. How much batter, or what other conditions determine when rail ends should be built up? How do you measure batter?	QUESTION 3. What is approximate number of joints built up during years 1931 and 1932 by oxy-acetylene or electric arc, and cost per joint.			
	By Oxy-acetylene	By Electric Arc Do you preheat?		Oxy-acetylene	Cost Per Joint	Electric-Arc	Cost Per Joint
1. Southern Pacific	Prior to 1926	Use electric only. Since 1926.	3/64" batter or when excessive chipping occurs. (Use 24" straight edge.)			1931-170,642 jts.	-
2. Baltimore & Ohio	Since 1924	1932 by contract.	3/64" batter, weld all chipped ends. (Use 18" straight edge)	No record	-	No record	-
3. Great Northern	Since 1920	-	2/64" to 4/64" batter depending on importance of line.	1931-12,731 jts. 1932- 1,951 "	$1.40 to $1.50	-	-
4. Northern Pacific	Prior to 1929	Since 1929 have used electric arc almost exclusively.	3/64" batter and all chipped joints. (Use 12" straight edge)	-	-	Approx. 10,000 jts. each year	Average $1.27
5. Canadian National	Since 1925	-	(.030) inch to 3/16" batter.	1931- 87,065 jts. 1932-202,275 "	-	-	-
6. New York Central	Since 1921	Since 1930 by contract - preheat.	1/32" batter or chipped ends. (Use 18" straight edge)	-	-	1931-21,000 jts. 1932- -	$1.95 to $2.10
7. Louisville & Nashville	Since 1926	-	General condition of rails, attempting to get worst stretches first.	1931-229,419 jts. 1932-229,103 "	*$0.51 .43	-	-
8. Illinois Central	Since 1921	Since 1928. Do not preheat.	3/64" batter.	1931-150,512 " 1932-158,747 "	$1.02 .92	1931 - 7,054 jts.	$1.60
9. C.M.St.P.& P.Ry.	Since 1928.	Have 5 machines but do little rail end work.	(.040-.100) inch although feel it desirable to weld ends where batter exceeds (.020) inches. (Use spring gauge).	1931- 56,884 " 1932-142,998 "	$1.15 .94	- -	- -
10. C.B.& Q.R.R.	Since 1923	Experimental only.	.030 inches if 50% or more joints in any given stretch of track or where chipped on high speed track.	1931-143,572 " 1932- 72,948 "	$0.70½ .74	- -	- -
11. C.& N.W. Ry.	Since 1924	Discarded electric welding rail ends.	This is a matter of judgment influenced by traffic.	1931-100 miles 1932-150 miles	$1.30	-	-
12. Pennsylvania	Since 1923	Started electric arc 1930-Do not preheat	1/32" to 1/8" batter - rail ends having less than 1/32" batter ground to an even surface.	1931- 1932-215,029 jts.	$1.20	1931- 1932-82,050 jts.	$0.88
13. Boston & Maine	Out of face 1928	1929-Do not preheat	.040" batter. Use AREA batter gauge for measuring.	1931 - None 1932 - "		1931 - None 1932 - "	
14. Canadian Pacific	Abandoned in 1929	1929-preheat only in cold weather.	3/64" batter, commence welding at.	None		1931-72,883 jts. 1932-75,979 "	$0.108 per in. of weld
15. New York, New Haven & Hartford	Since 1920		Riding condition and observation of rail.	1933 program "out of face"	$1.15	-	-
16. Southern Ry.	Since 1920	-	General inspection.	1931) Large 1932) number	$0.60 to $1.00	-	-
17. Atlantic Coast Lines	Since 1922	-	1/16" batter measured by straight edge across joint.	No record	Average $0.90	-	-
18. Reading Company	Since 1925	-	1/32" batter. However, most of rail ends need building up account flaking or chipping.	1931 - 673 jts. 1932 - 438 "	$0.99	- -	- -
19. Central of Georgia	Since 1917	-	Track Supervisor marks joints.	1931-No record 1932-17,503 jts.	$0.89	-	-
20. Santa Fe Ry.	Since 1917	Experimental only. Do not preheat.	.030" to 3/64" depending on money available for rail end work.	1931-136,983 " 1932- 36,209 "	$0.97 $0.95	-	-
21. C.R.I.& P.Ry.	Since 1923	1930-Do not preheat.	.040 or more, consider ready for welding.	1931 - 65 miles 1932 - 32 miles	$0.12½ per in. weld.	Use when power plant handy.	$0.10 per in. weld.
22. C.& O. Ry.	Since 1923	Experimental only.	1/16" limit before welding on high speed track - low speed more batter allowed.	1931-147,639 jts. 1932-130,251 "	$0.91 $0.83	- -	- -
23. Pere Marquette	Since 1925	Since 1930 by contract. Some preheating done 1933.	1/32" to 1/16"-use 18" straight edge and taper gauge.	1931 - 313 " 1932 - 6,034 "	- -	10,432 jts. 19,530 "	Contract
24. M.K.& T.Lines	1922	Oxy-acetylene only	1/32" batter - use rail batter gage and straight edge.	1931 - 7,073 " 1932 - 3,251 "	(#) (#)	- -	- -
Summary	Approximately 50% of railroads reporting use oxwelding only; Canadian Pacific, Northern and Southern Pacific use electric arc only; remainder both methods, a few railroads preheat ahead of electric welding.		Amount of batter determining when welding should be done varies from 1/32" to 1/8". However, majority of railroads reporting indicate that rail ends with batter of 3/64" require welding.	Of the railroads above reporting for year 1932, approximately 85% of joints were built up by the oxy-acetylene process. Cost Range {Oxy-acetylene $.43 to $1.50 per joint Electric arc $.88 to $2.10 " "}			

* Includes some joints where no metal added.

For "out of face" $0.77.
For spot welding $1.37.

Recapitulation of Answers Received from A.R.E.A. Questionnaire

Committee V-Track - Sub-Committee 13.

Recapitulation of Answers Received from A.R.E.A. Questionnaire

Committee V-Track - Sub-Committee 13.

Railroads	QUESTION 4. What is your Rail End Welding Organization for -		QUESTION 5. A-How many years after laying Main Track Rail do you build up your chipped or battered rail ends; average annual tonnage above track. B-How many years does reconditioned rail ends hold up before requiring a second rebuilding. C-What has been your experience in having secondary batter occur back of weld.			QUESTION 6. A-What Increase in life of Main Track Rail in first position do you expect to secure by reconditioning rail ends by either method. B-Do you handle Rail End Welding by Contract or Company forces.	
	Oxy-acetylene	Electric Arc	(A)	(B)	(C)	(A)	(B)
1. Southern Pacific	-	2 welders + helpers 4 machine men	6 to 7 yrs. approx. 10 M. Tons tangent.	4 to 5 years.	Only to limited extent.	20% Increase life of rail.	Company Forces.
2. Baltimore & Ohio	Finish with flatter	2 welders + helpers 4 machine men	Depend on physical condition.	Done little second welding.	Some on old rail.	30% longer life.	Both.
3. Great Northern	Finish with flatter	-	3 yrs. 15 M tons, depending on conditions	5 to 8 years.	Yes - account harder welds	From 4 to 10 yrs.	Co.forces-12 yrs. Some contract 1932.
4. Northern Pacific	-	Arc welder - track grinding machine.	Varies.	Joints with 5 yr. life O.K.	No experience.	Increase of many years.	Company forces.
5. Canadian National	Flatter finish altho grinding machines used on some parts of System.	-	Varies widely.	Six years.	No experience.	Increase life. Varies greatly.	Company forces.
6. New York Central	At present using grinding machines to finish.	One welder to each grinding machine.	Approx. 7 years. No record of tonnage.	Joints with 3 yr. life O.K.	No experience.	Extend life of rail at least 5 years.	Both Contract and Company Forces.
7. Louisville & Nashville	Finish with flatter	-	-	-	No experience.	Process no doubt economical.	Company Forces.
8. Illinois Central	Four welders with grinding machine, also finish with flatter.	-	4 to 10 yrs. depending on tonnage.	3 to 8 years.	Little trouble.	Minimum of 3 yrs. additional life.	Both
9. C.M.St.P.& P.Ry.	Welders bunched ahead of grinding machine.	-	5-6 yrs. approx. 10 M. tons	8 yrs. service O.K.	Yes-due to hardness of weld.	Twice life of rail.	Company Forces
10. C.B.& Q.R.R.	4 to 6 welders + helpers. Finish with flatters.	-	3-15 yrs. depending on tonnage.	5 to 10 yrs.	No trouble.	25% Increase.	Company Forces.
11. C.& N.W. Ry.	2 to 6 welders. Finish with flatter.	-	No record.	-	Small amount.	5 to 10 yrs. Increase	Company Forces.
12. Pennsylvania	5 welders + helpers Finish with flatter	2 welders + helpers 2 trk.grinding mchs. 1 cross grinder.	4 to 5 yrs. under 15 M. tons traffic	3 to 5 years.	No experience.	3 to 5 years Increase	Both-but principally Co. Forces
13. Boston & Maine	8 welders + helpers Finish with flatter	One welder One grinding machine	No record.	Approx. 5 yrs.	Some slight experience.	10 to 33% Increase.	Oxy-acetylene - Company Forces. Electric - Both.
14. Canadian Pacific	-	Welder ahead of each grinding machine.	Varies	6 to 7 years.	Little trouble.	30 to 40% Increase.	Company Forces.
15. New York, New Haven & Hartford	Bunch welders ahead of grinding machine	-	8 yrs. or more on 15,000 annual tonnage	No experience.	Very little experience.	At least 50% increase.	Company Forces.
16. Southern Ry.	Finish with flatter.	-	No definite time.	No experience.	Very little trouble.	Considerable	Company Forces.
17. Atlantic Coast	Finish with flatter	-	3 to 4 yrs. depending on traffic.	About 5 years.	No trouble.	-	Company Forces.
18. Reading Company	Finish with flatter	-	Approx. 8 yrs. under 12 M. Tons traffic.	No experience.	No trouble.	3 to 4 yrs. Increase.	Company Forces.
19. Central of Georgia.	Finish with flatter	-	Approx. 4 years.	Approx. 8 yrs.	Depends on quality of weld.	-	Company Forces.
20. Santa Fe Ry.	Bunched welders with grinding machine also. Finish with flatter.	-	Approx. 5 yrs.under traffic of 10 M tons.	5-6 years.	No trouble.	5 to 10 yrs. Increase.	Company Forces Test of Electric Welding by Contract.
21. C.R.I.& P.Ry.	Bunched welders with grinding machine also. Finish with flatter.	One electric welder for each grinder.	Conditions govern.	-	Little trouble.	50% Increase.	Company Forces.
22. C.& O.Ry.	Gang of 2 to 6 welders. Finish with flatter.	-	2 to 7 yrs.Estimated 130# rail will carry 75 M. Tons.	If not heat treated about 2 years.	No trouble.	50-60% Increase.	Company Forces.
23. Pere Marquette	Gang organization using grinder.	Contract	4 to 6 years on new rail.	Have done no second welding	No trouble.	Approximately 50% increase	Oxy-acetylene - Company Forces. Electric-Contract.
24. M.K.& T.Lines	1 welder+1 helper each district. Finish with flatter.	-	5 to 6 years.under 10 M tons.	5-6 years.	No trouble.	20-25% Increase	Company Forces.
Summary	30% of Roads using oxy-acetylene method report use of grinding machines for finishing welds. All electric-arc using grinding machines, usually one grinder to each arc.		From above reporting roads, carrying annually 10 M. tons or better, it is apparent that rail ends, either from batter, chipping or combination require rebuilding after from four to five years' life. A few roads report that secondary batter occurs back of weld account of weld being harder than the parent metal.			From replies of reporting roads, it appears that the rebuilding of rail ends increases the life of main track rail in first position from 50 to 100%. All oxy-acetylene welding done by Company forces; electric welding approx 50-50 Company Forces - Contract.	

Appendix M

(12) RECLAMATION OF SERVICEABLE MATERIALS FROM SCRAP AND RETIRED MAINTENANCE OF WAY AND STRUCTURE MACHINES, TOOLS AND APPLIANCES

J. R. Watt, Chairman, Sub-Committee; T. T. Irving, W. A. Murray, G. A. Peabody, W. L. Roller, G. L. Sitton, J. G. Wishart.

The Committee reports progress. Information on this subject is not developed sufficiently to warrant a report this year.

Appendix N

(13) METHODS OF RECONDITIONING OF RAIL ENDS, FASTENINGS, FROGS AND SWITCHES IN TRACK

G. M. Strachan, Chairman, Sub-Committee; M. D. Bowen, F. W. Hillman, H. D. Knecht, O. C. Rehfuss, C. J. Rist, G. J. Slibeck.

There is submitted herewith in tabular form replies to questionnaire sent out by the Sub-Committee. The twenty-four railroads reporting are among the largest in the United States and Canada and represent all sections of the country; therefore, the information developed may be taken as fairly representative of the present trend of track welding.

The earliest date recorded for oxwelding of rail ends was 1917, while one road reports starting work by this process as late as 1928. The first electric-arc rail end welding is given as 1926. In the early years, all the work done by the oxy-acetylene process was by company forces using flatter for finishing the welds. The application of electric-arc welding to rail ends brought out a grinding machine for the finishing and this grinding restores the rail end more uniformly to original contour at little, if any, increased cost. Its use, therefore, has spread to oxwelding. A grinding machine, of which there are several designs on the market, can usually keep pace with the double arc electric welding unit or with a gang of five or six oxy-acetylene welders.

A study of the replies as regarding costs reported for the building up of rail ends on various railroads indicates considerable variation, cost depending primarily on the amount of batter and the length of weld, also, whether or not the rail ends are built up "out-of-face" or spot welded. Differences in accounting for labor, material and overhead are noted in various replies submitted, the majority of roads basing their costs on unit rate per joint, others on per inch of weld, while some compare costs on per pound of metal deposited. So many variables enter into welding work that cost figures from one road cannot be compared to those obtained from another road unless complete history is available.

The amount of batter determining when welding should be done varies from $\frac{1}{32}$ to $\frac{1}{8}$-inch. However, the majority of railroads indicate that on high speed main tracks the rail ends with an average batter of 3/64-inch require welding "out-of-face." Replies further indicate that either from batter, chipping or a combination of the two, rail ends of track carrying annually ten million tons or better require building up after a four or five-year life, and that these rail ends, after being rebuilt, give a similar average service life before requiring a second rebuilding. That this handling of rail ends is economical is indicated by replies to Question 6, and as stated in summary, the rebuilding of rail

ends increases the life of main track rail in first position from 50 per cent to 100 per cent. By either method of rebuilding first-class results can be secured. Failures reported are negligible, being only a small fraction of one per cent.

Reports indicate that roads using oxy-acetylene for the reconditioning of their rail ends, frogs and switches, handle this work by company forces. Of the roads using electric arc, some handle the work by contract, others by company forces.

Conclusion

Your Committee believes that this assignment is a very important subject, and recommends that this report be received as information.

Appendix O

(14) DETERMINATION OF THE LIMITING RELATIVE POSITIONS OF THE ABUTTING RAILS OF FIXED AND DRAW SPANS ON BRIDGES AND PROPER TOLERANCES

L. H. Bond, Chairman, Sub-Committee; W. G. Brown, F. H. Masters, J. C. Mock, I. H. Schram, Theo. Speiden, Jr., J. R. Watt.

The Committee reports progress. Information on this subject is not developed sufficiently to warrant a report this year.

Appendix P

(15) DAMAGE TO TRACK AND DEVICES DUE TO BRINE DRIPPINGS FROM REFRIGERATOR CARS

W. G. Arn, Chairman, Sub-Committee; W. J. Harris, A. A. Johnson, G. M. Strachan, J. G. Wishart.

The Sub-Committee from this Association working with the Mechanical Division Sub-Committee, joined in the following report;

CONCLUSIONS AND RECOMMENDATIONS OF JOINT SUB-COMMITTEE ON DAMAGE TO TRACK AND DEVICES DUE TO BRINE DRIPPINGS FROM REFRIGERATOR CARS

"Your Committee has analyzed the data gathered by the former committee appointed in 1928. In addition, another field inspection has been made for the purpose of disclosing conditions obtaining at this time on refrigerator cars equipped with brine tanks. This reveals that out of 504 brine tank cars inspected, 32.9 per cent were found defective, while in 1928, when a similar inspection was made, 61.3 per cent were found defective. This shows a marked improvement over conditions existing.

"The Committee believes, however, that there is still room for further improvement, and in order that this may be brought about, it is suggested that, so far as may be practicable, the mechanical inspection department be authorized to make periodic inspection of brine tank cars at loading stations or other suitable locations, the results of these inspections to be transmitted currently to the Secretary, Mechanical Division, and that he, in turn, notify owners of any cars found having brine tanks or fittings in defective condition together with the station involved, with the suggestion that the necessary corrective measures be immediately taken.

"As to open bunker cars, the committee has given consideration to the practicability of equipping these cars with suitable containers for retaining brine between icing stations as well as the cost of application. It is estimated that it would cost $282.00 per car to install containers. The committee has prepared several designs of tanks but is unable to conceive of any constructions which would be economical or entirely practicable. On the basis proposed, it would mean a total expenditure of $39,198,000.00.

"To equip the cars with brine containers would seriously impair their carrying capacity as the containers themselves would weigh approximately 3000-lb. and, when filled, would weigh approximately 12,500-lb. This would essentially reduce the load carrying capacity of a 40-ton capacity car to that of a 30-ton car, and could be overcome only by the application of higher capacity trucks at an estimated cost of $400.00 per car. Such procedure would, however, affect the nominal capacity of the equipment and also affect the tariff structure. The estimated cost of installing brine containers and changing trucks on existing 40 and 50-ton nominal capacity cars would be:

$$139{,}000 \times \$282.00 = \$39{,}198{,}000.00$$
$$103{,}200 \times \$400.00 = \$41{,}280{,}000.00$$
$$\$80{,}478{,}000.00$$

"The foregoing does not take into consideration the cost of tank renewals, repairs, inspection and cleaning, which is estimated would amount to $100.00 per car, per year, or a total of $13,900,000.00, nor the cost of changing trucks on 35,800 30-ton cars. Neither is included the additional cost of hauling the excess weight, the additional maintenance cost on account of higher capacity trucks, if applied, interest on the increased capital investment, nor the possibility of damage to cars and lading due to clogging or freezing of pipe fittings and tanks.

"The Sub-Committee, Engineering Division, has tabulated estimates received from railroads reporting damages to tracks, bridges, and signals, through brine drippings from refrigerator cars which indicate that an annual excess maintenance expense of $2,350,000.00 is incurred from this cause on approximately 17,938 miles of main tracks. This figure includes both the cost of damage to material and of protection against such damage.

"On the basis of this amount of annual damage to tracks, bridges and signals, the capital expenditure which would be justified at 5 per cent interest is $42,000,000.00 while the estimated cost of equipping open bunker type cars only is estimated at $39,000,000.00 to which should be added such additional sums required for changing to higher capacity trucks, maintenance, etc. Clearly, this expense is not justified for the saving that might be made especially as the open bunker type car contributes only a part, and possibly a minor part, of the damage from brine, the balance coming from the cars equipped with brine retaining devices due to defects in this equipment.

Recommendations

"A higher degree of maintenance of tanks and fittings on existing brine tank equipment and better protection of tracks, bridges and signals against brine drippings. Under existing circumstances this seems the most economical and practical procedure."

It is recommended that the subject be dropped, at least until such time as there are developments which would make it worthwhile to revive this subject.

REPORT OF COMMITTEE VIII—MASONRY

M. Hirschthal, *Chairman;*
F. E. Bates,
G. E. Boyd,
Kennerly, Bryan, Jr.,
Kennerly,
M. F. Clements,
Maurice Coburn,
T. L. Condron,
Hardy Cross,
W. F. Cummings,
Theo. Doll,
G. F. Eberly,
L. V. Haegert,
W. K. Hatt,
A. C. Irwin,
A. R. Ketterson,
J. A. Lahmer,
A. N. Laird,
O. V. Parsons,
I. L. Pyle,
W. M. Ray,
C. P. Richardson,
Geo. E. Robinson,
D. A. Ruhl,
D. B. Rush,
F. E. Schall,
C. P. Schantz,
L. W. Skov,
J. F. Leonard, *Vice-Chairman;*
G. R. Smiley,
A. W. Smith,
I. F. Stern,
G. E. Tebbetts,*
H. H. Temple,
Jamison Vawter,
L. W. Walter,
C. A. Whipple,
C. C. Williams,
D. E. Woozley,
W. K. Wyatt,
J. J. Yates,
Committee.

* Deceased December 13, 1933.

To the American Railway Engineering Association:

Your Committee on Masonry respectfully presents herewith reports covering the following subjects:

(2) Specifications and principles of design of plain and reinforced concrete (Appendix A).

(3) Progress in the science and art of concrete manufacture (Appendix B).

(5) Specifications for foundations (Appendix C).

(6) Methods and practices of lining and relining tunnels (Appendix D).

(7) Specifications for concrete to be applied by propelling machines of the type of the "cement gun", (Appendix E).

(8) Design of expansion joints involving masonry structures (Appendix F).

The Committee reports progress on

(1) Revision of Manual;

(4) Contact with Joint Committee on Standard Specifications for Concrete and Reinforced Concrete;

(9) Study Specifications for overhead highway bridges as prepared by the Association of State Highway Officials.

Action Recommended

(1) That Section 1, Appendix A, be approved for printing in the Manual as Recommended Practice.

(2) That the definitions of Appendix C, be approved for printing in the Manual.

(3) That Section 2 of Appendix A, Appendix B, remainder of C, and Appendices D, E and F, be received as information.

Respectfully submitted,

The Committee on Masonry,
Meyer Mirschthal, *Chairman.*

George E. Tebbetts

The Committee was greatly shocked by the announcement of the sudden death of George E. Tebbetts, Engineer of Structures, Chicago Rapid Transit Company. Mr. Tebbetts died December 13th, following an operation. His loss will be deeply felt by both the Committee and the Association.

Appendix A

(2) SPECIFICATIONS AND PRINCIPLES OF DESIGN OF PLAIN AND REINFORCED CONCRETE

A. N. Laird, Chairman, Sub-Committee; J. F. Leonard, F. E. Bates, T. L. Condron, Hardy Cross, Theo. Doll, A. C. Irwin, A. R. Ketterson, C. P. Schantz, L. W. Skov, A. W. Smith, I. F. Stern, Jamison Vawter, C. C. Williams.

Your Committee reports progress on the subject of Reinforced Concrete Arches and presents the following report as information and for suggestions in continuation of the subject reported on last year. It is the intention during the coming year to review the subject-matter contained in this report together with that previously submitted and present it at the next convention in the form of Specifications for the Design and Construction of Reinforced Concrete Arches for Railroad Loadings, for adoption by the Association as recommended practice.

Section 2

(I) REINFORCED CONCRETE TRESTLE DESIGN—E-60 LOADING

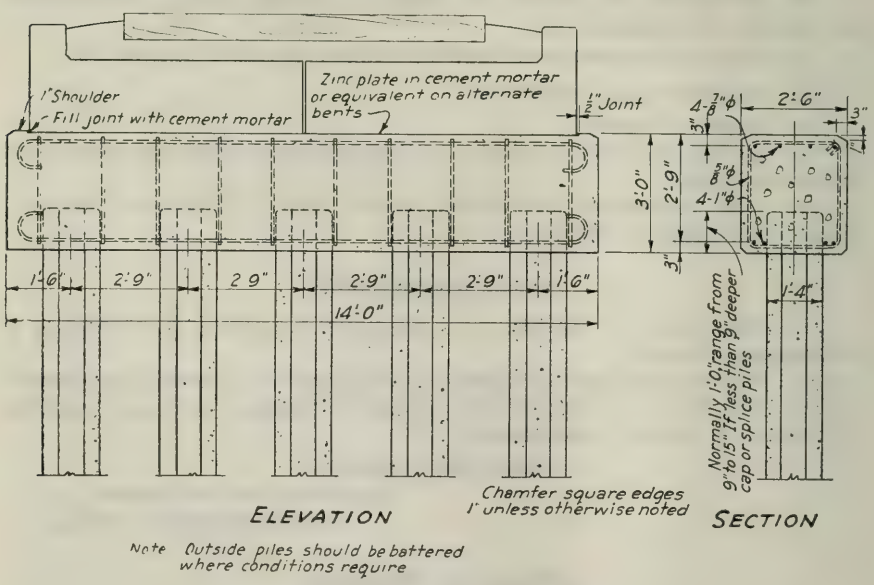


Fig. 1.—Design for Single Bent.

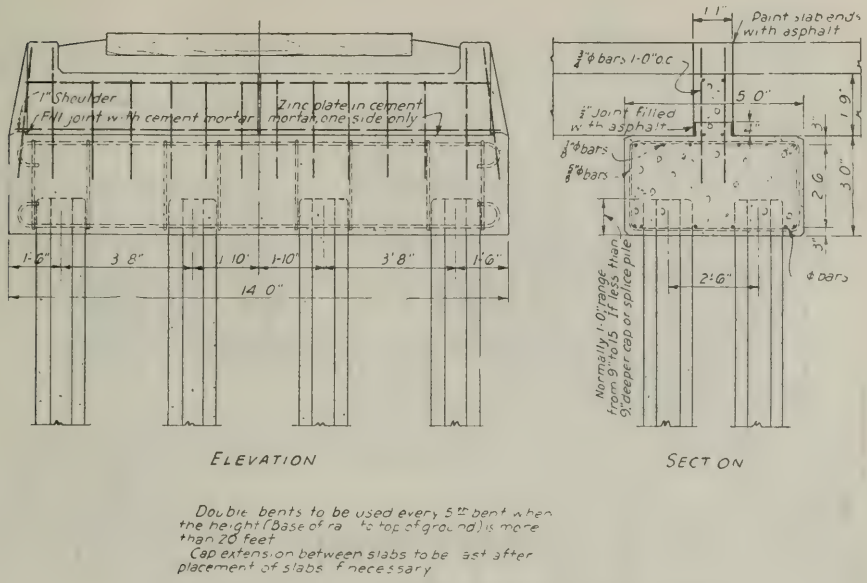


FIG. 2.—Design for Double Bent Reinforced Concrete Trestle.

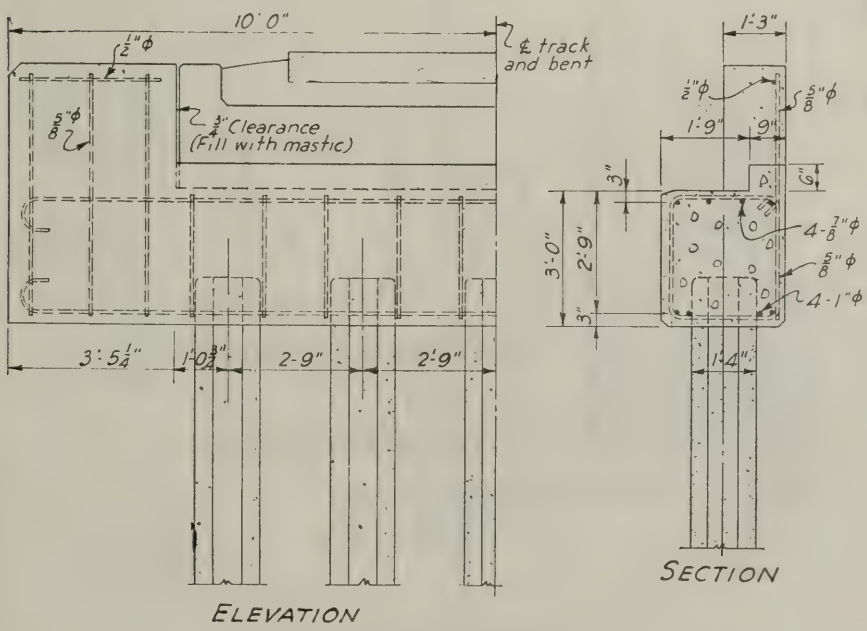
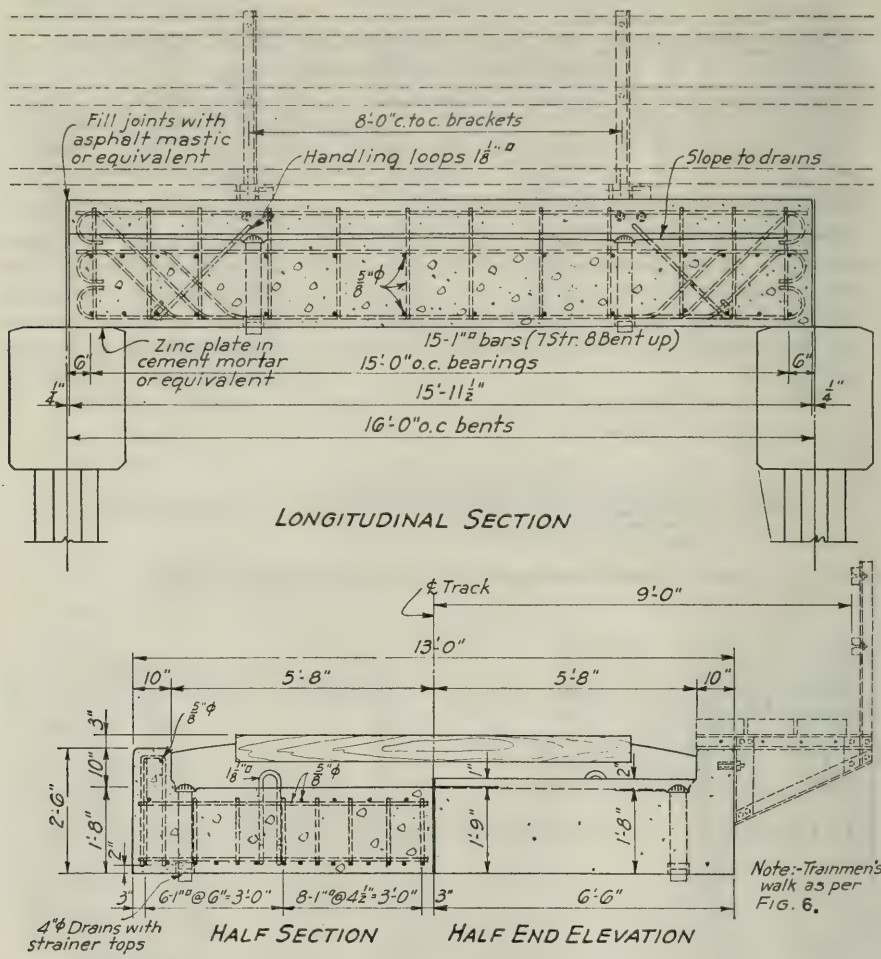


FIG. 3.—Design for End Bent.



General notes:-
Designed in accordance with specifications for Portland Cement concrete, plain and reinforced of the A.R.E.A (Manual 1929)
Class of concrete - 3500
Grade of reinforcing steel - Intermediate
Live load - Coopers E 60
Impact - 50% added to weight on drivers for slabs and 25% for piles.
Handling stresses - Top bars in slabs for handling with stirrups and for center blocking
Allowable load on piles = 30 ton.
Chamfer square edges 1" unless otherwise noted

FIG. 4.—Design for Slab.

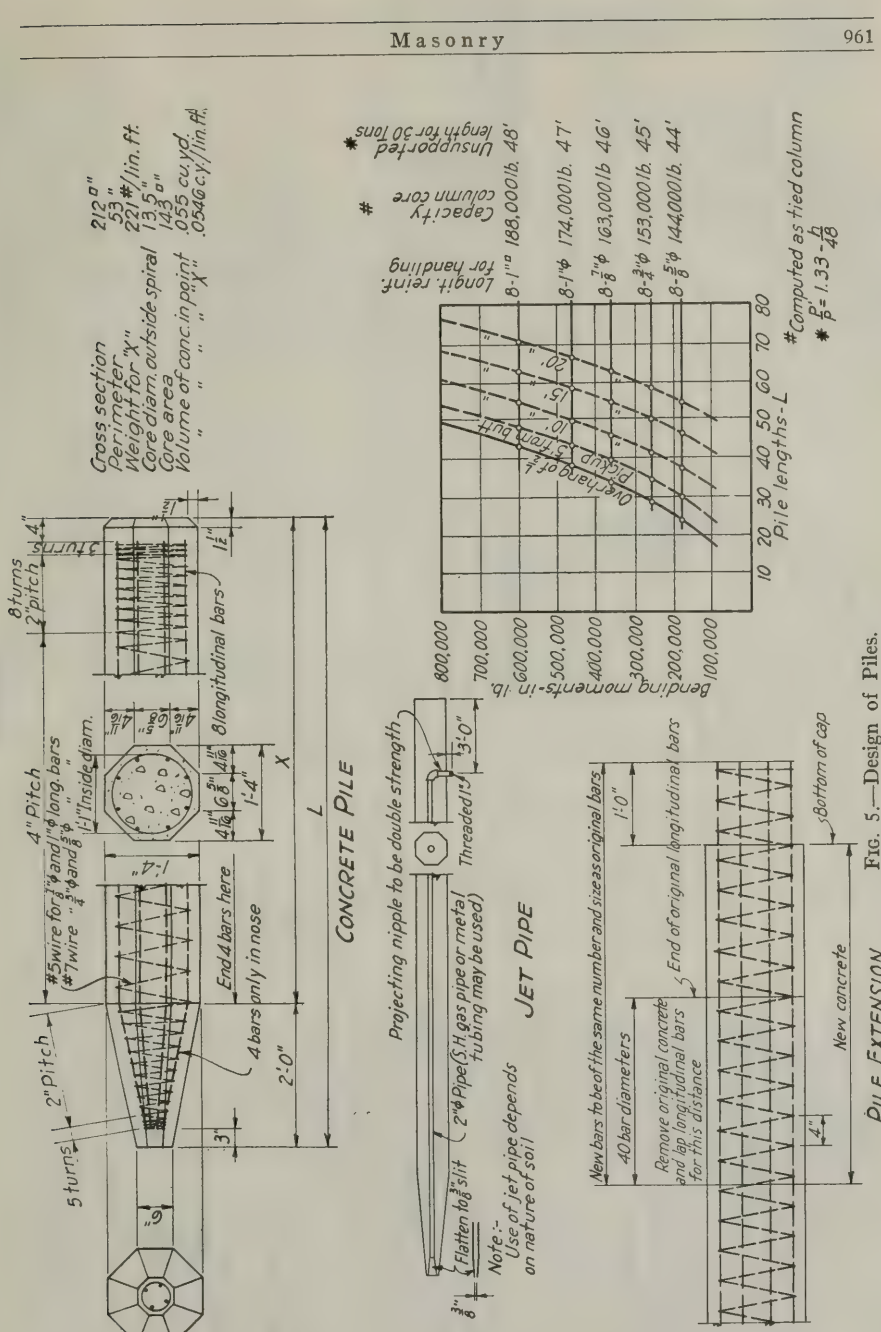


FIG. 5.—Design of Piles.

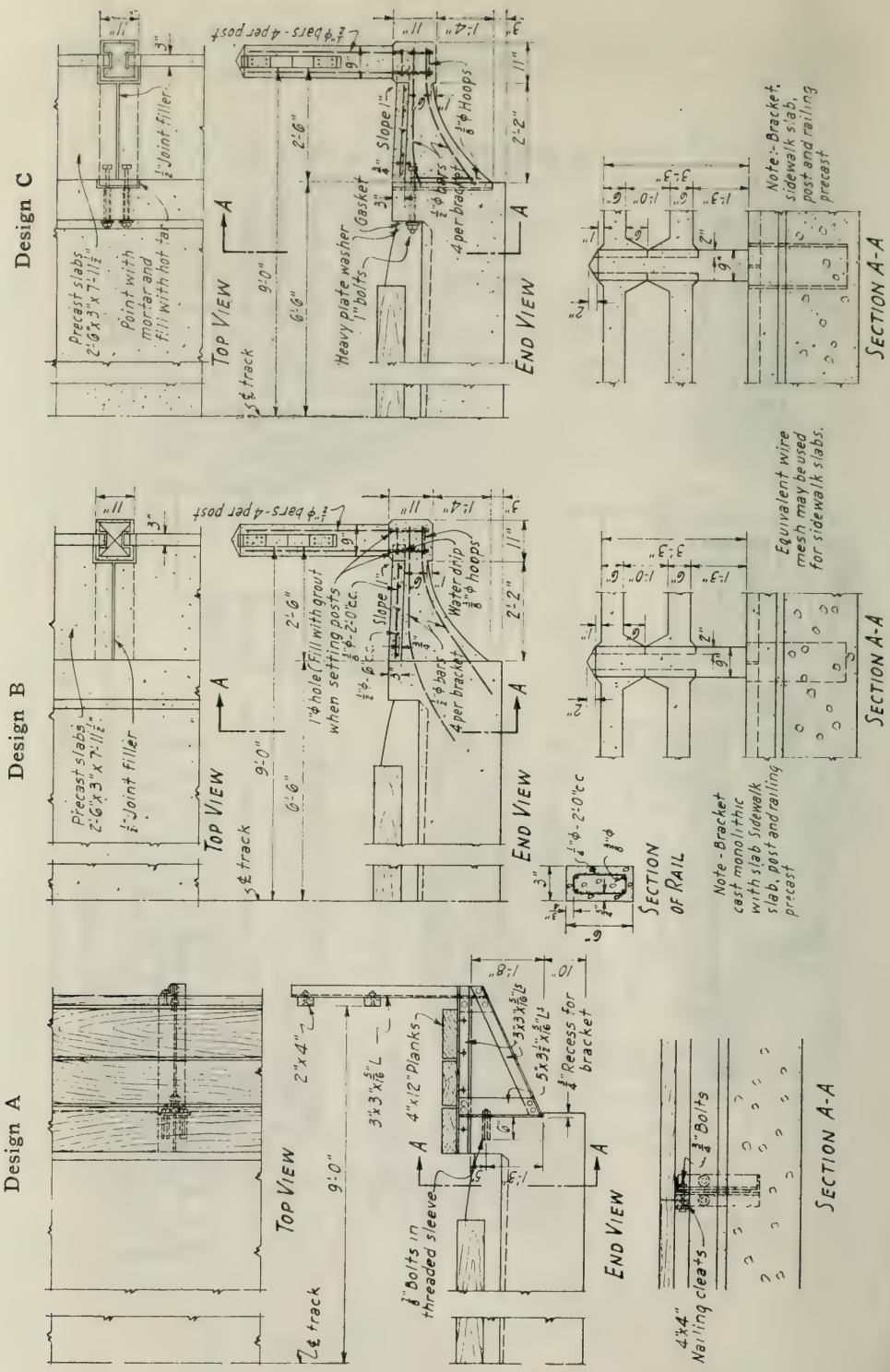


FIG. 6.—Trainmen's Walks—Details.

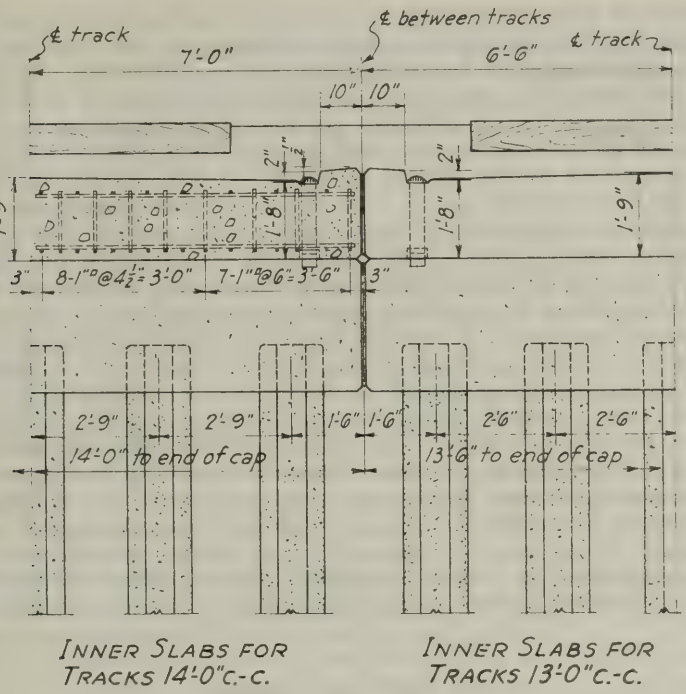


FIG. 7.—Slabs and Bent for Multiple Track.

(II) DESIGN AND CONSTRUCTION OF REINFORCED CONCRETE ARCHES (Continued)

8. Piers and Abutments

Arch piers and abutments shall be designed to resist the forces resulting from dead load, combined with the most unfavorable condition of live loading, together with temperature and shrinkage distortions and from distortions of the foundation beds. The stresses at critical sections between springing line and footing, including those resulting from the effect of unbalanced thrusts from adjoining arch rings or ribs shall be carefully analyzed. The bearing areas shall be proportioned so that the allowable pressures on the foundation beds shall not be exceeded and that settlement, if any, shall be uniform.

The stability of arch piers shall also be investigated for conditions of loading during the construction period, including the effect of unbalanced thrust from arch rings or ribs, and distortion due to temperature changes and shrinkage. In long structures, intermediate piers at intervals shall for construction purposes be designed as abutment piers to withstand such forces from one side of the pier only, without assuming support on the other side. Such abutment piers shall be clearly designated on the plan.

In the design of arch abutments the change in distribution of pressure to the foundation beds resulting from the application of earth pressure against the back of the abutment, with and without the addition of live load surcharge, in accordance with

usual practice in the design of abutments, shall also be investigated, and the allowable pressures on the foundation beds shall not be exceeded under such conditions of loadings. In case of rotation of the arch abutment as a result of unequal distribution of pressure on the foundation beds, or in case horizontal movement as a result of the horizontal component of the thrust on the abutment appears possible, the effect of such movement on the arch ring or ribs should be investigated. The form of abutment shall be selected such that the resultant line of pressure shall preferably lie within the middle third of the base and as close to the center of the base as practicable. Insofar as practicable, the forces tending to produce sliding of the abutment shall be resisted, in combination with the vertical components of the dead load and arch thrust, by direct bearing on the foundation. Where this is impracticable, the frictional resistance of the footing slab on the foundation and the bearing resistance of abutting undisturbed material against back of abutment may be considered as assisting the stability against sliding. Additional resistance may be provided, if required, by the construction of a key or drop wall extending below the footing slab, in direct contact with undisturbed foundation material.* Where permanent cofferdam construction encloses the foundation, this may be considered as increasing the lateral bearing area against undisturbed material for resistance to sliding. Where the foundation rests on permanent piling or caisson construction, the horizontal component of batter piles or caissons may be considered in determining the resistance to sliding. Where the angle of the arch axis is skewed with the face of the abutment or pier, adequate provision shall be made for the transmission of the transverse component of the arch thrust to the pier of abutment proper, in addition to the longitudinal reinforcement required at the skew back.

(III) DETAILS OF DESIGN

1. General

The design drawings shall be prepared in such detail as to clearly indicate all important elements of the construction, dimensions, spacing and size of reinforcing bars, construction and expension joints, waterproofing, drainage and maximum foundation pressures or pile loads.

2. Spandrel Construction

(a) Open Spandrel Type

In open spandrel construction, the deck slabs and beams shall be considered as continuous members between expansion joints, and shall be reinforced accordingly. Transverse bars shall be provided in the bottom of deck slabs for the full length thereof, and in the top of the slabs over supports between quarter points of adjoining spans.

Flat slab spandrel construction shall conform to the requirements of the A.R.E.A. standard specifications therefor.

Spandrel arches shall be reinforced longitudinally parallel with both extrados and introdos using not less than 0.2 per cent of the arch section at the crown. Transverse reinforcement shall be provided for arch rings.

Spandrel columns shall conform to the A.R.E.A. standard specifications for Columns. Transverse walls shall be treated as columns with lateral ties. They shall be reinforced parallel with both faces, both horizontally and vertically.

* It is recommended that in such cases, not more than 50 per cent of the estimated frictional resistance between the footing slab and foundation, together with not more than 50 per cent of the allowable foundation bearing pressure per square foot, for equivalent material, be used in computing the resistance to sliding due to key or drop wall and to abutting undisturbed material against back of abutment.

(b) Filled Spandrel Type

In filled spandrel construction the spandrel walls may be of gravity, cantilever or counterfort design or tied back with transverse walls. Counterfort or cantilever construction shall be proportioned and reinforced to minimize transmission of torsional stresses to outer section of the arch ring. The face of the spandrel walls shall be reinforced in two directions for temperature.

3. Arch Ring and Ribs

Arch rings and ribs shall be reinforced in planes parallel to both intrados and extrados. Longitudinal reinforcement shall be provided as required by the arch stresses but not less than 0.2 per cent of the area of the crown section shall be used both top and bottom. Transverse reinforcement shall be provided for arch rings.*

Bearing seats for columns and transverse walls over arch rings or ribs shall be horizontal with suitable dowels to anchor to the spandrel construction. The spandrel wall reinforcement in filled type arches shall preferably extend into the arch ring with adequate anchorage to develop the strength of the bars in bond.

4. Abutments, Piers and Footing Slabs

Abutments, piers, and footing slabs shall conform to the requirements of Sections 127 to 135, inc., of the standard specifications of the A.R.E.A. therefor.

5. Construction and Expansion Joints

The requirements of the A.R.E.A. standard specifications, Sections 57 to 63, inc., covering construction and expansion joints shall be complied with.

Construction joints required to transmit stress shall be keyed and reinforced across the joint. Longitudinal construction joints in arch rings shall be vertical, and parallel to the longitudinal axis of the structure. Transverse joints in arch rings or ribs shall be radial. Horizontal construction joints shall not be permitted in arch rings or ribs and shall be avoided where possible in other portions of the construction except where required by construction limitations and to permit proper shrinkage of the concrete in such members as columns. Such construction joints shall be clearly designated on the plans.

In skew arch construction the joints at the springing line may consist of a series of stepped joints, each perpendicular to the line or thrust of the arch ring or ribs, or in the case of solid ring construction, may be on the line of the face of the pier or abutment, but provision shall be made in such cases by special anchorage, keys and reinforcing to transmit the transverse component of the arch thrust to the piers and abutments.

Vertical expansion joints shall be provided in open spandrel construction at or near the face of piers and abutments and, depending on the length and shape of the arch span, at points of the span. In longer structures, these may be required at intermediate intervals. In filled spandrel construction, the expansion joints in the spandrel walls shall be provided as required for open spandrel construction and in addition shall be spaced not more than 30 feet apart.

6. Drainage

Adequate drainage shall be provided where water may collect. Nominally horizontal surfaces exposed to moisture shall be sloped for drainage. Deck slabs shall be given a slope preferably ¼-in. per foot and not less than ⅛-in. per foot, if practicable,

* Transverse bars ⅝ in. round spaced 18 in. centers or the equivalent thereof placed in both top and bottom of arch ring outside of the longitudinal bars are recommended as a minimum requirement.

away from expansion and construction joints. A raised lip shall be constructed at such joints to prevent impounded water from overflowing into the joint. Suitable ballast guards and flashing shall be provided at all deck drainage openings with lead-out pipes to prevent water falling on surfaces of the structure. Weep holes or pipe drains shall be provided for drainage of backs of abutments to prevent impounding of the water. Pipe openings shall be provided through all transverse walls or other members which would interfere with the normal flow of water, in accordance with the drainage layout. Provision shall be made for ultimate disposal of the water in accordance with the local requirements of the site.

7. Waterproofing

The deck surface of open spandrel slabs or arches and the extrados of filled arches shall be waterproofed using a membrane type of waterproofing and a protective covering in accordance with the standard specifications therefor of the A.R.E.A. Backs of abutments above the footing slab shall be damp proofed. All construction and expansion joints exposed to water, or in contact with soil or filling materials, including ballast, shall be waterproofed with a membrane type of waterproofing as specified for deck construction and shall preferably have a sheet metal water stop of non-corrosive material equally embedded in both sides of the joint for the full length thereof. Where the joint is designed for expansion this sheet metal water stop shall be looped to provide for the movement. Suitable keyways shall be constructed at construction and expansion joints where the details will permit except where one surface is designed to slide upon the other.

(IV) CONSTRUCTION

1. General

The General Specifications for Plain and Reinforced Concrete of the A.R.E.A. shall apply hereto insofar as consistent, subject to such modifications as provided herein, or by the detailed plans which shall be rigidly adhered to.

The Contractor shall submit a detailed construction schedule for approval by the Engineer.

2. Arch Ring and Rib

(a) Centering

The contractor shall submit designs for the arch centering for approval by the Engineer. Arch centering shall be of rigid construction conforming to the shape of the arch ring or ribs, with adequate foundation bearing area, piling or other suitable construction to sustain the dead load of the concrete while it is being placed, construction equipment, spandrel forms, etc. It shall be braced in both longitudinal and transverse directions and shall be constructed with oak wedges, or sand boxes or other devices for adjusting the shape of the arch ring and for striking the centering gradually and uniformly after the concrete has cured sufficiently. Allowance shall be made in the form and elevation of the arch centering for the dead load deflection of the arch. When local conditions such as waterway, roadway, or other conditions demand that specific clearances be provided under the structure during construction, such as to require that a long span be used for centering, allowance shall be made when setting the forms for the deflection of such span due to its own dead load and to the dead weight of the wet concrete to be supported, and suitable means shall be provided for adjusting the forms to their proper contour. Arch centering shall not be struck or removed until the concrete has sufficiently cured to maintain its own weight and that of the spandrel construction.

(b) Concreting Methods

The concrete shall be placed for each rib or ring or subdivision thereof in a symmetrical order with relation to the arch piers to minimize springing or distortion of the arch centering, and unequal loading of arch piers. The sections to be placed in one day shall consist either of longitudinal strips for the full length of the arch span conforming in width to the established location of construction joints or voussoir sections, of such length as designated on the plans leaving open joints with suitable dowels, and keys to engage later sections. The schedule of placing concrete shall be submitted by the contractor for approval by the Engineer in accordance with the requirements of the drawings.

3. Spandrel Construction

The concrete portion of the spandrel construction shall not be placed until concrete of arch ring or ribs has sufficiently cured to withstand the super-imposed load and until arch centering has been struck. In open spandrel construction concrete for columns and transverse walls shall be placed to the underside of the floor slab or to the springing line of spandrel arches and permitted to remain for a period directed by the Engineer before proceeding with the placement of the balance of concrete of the spandrel construction. Centering and bracing for spandrel construction shall remain in place until slab or spandrel arch concrete is placed.

Filling materials for placement over arch rings and behind arch abutments shall be of porous structure which will permit rapid drainage. Filling materials shall be placed uniformly and symmetrically in horizontal layers, and properly compacted. In filled spandrel construction, the filling material shall be placed uniformly for each span commencing at piers and working toward the crown. In multiple span structures this filling operation shall preferably be carried on uniformly for all spans between abutment piers at substantially the same time. Puddling of filling material over the arch ring will not be permitted.

Appendix B

(3) PROGRESS IN THE SCIENCE AND ART OF CONCRETE MANUFACTURE

L. W. Walter, Chairman, Sub-Committee; Maurice Coburn, L. V. Haegert, W. K. Hatt, A. C. Irwin, J. A. Lahmer, O. V. Parsons, W. M. Ray, D. A. Ruhl, D. B. Rush, W. K. Wyatt.

Section I

VIBRATION IN PLACEMENT OF CONCRETE

The first important application of vibration to the placement of concrete was in connection with the construction of concrete ships during the World War. Successful placement of concrete in the heavily reinforced thin walls and structural parts of these ships would have been well nigh impossible by any other means. Vibration in these cases was accomplished by applying air hammers direct to the forms. These hammers were doubtless inferior in effect to present equipment for external vibration.

In the present state of the art, vibration may be defined as a method of assisting concrete into place by increasing its mobility through rapidly applied impulses. Theoretically, these impulses should be repeated so rapidly that particles do not stabilize between them. There is a marked difference in the results obtained by jarring or jigging

at rather low frequency compared with high frequency vibration. Observations indicate that the effectiveness of vibration increases with the frequency of the impulses but definite information is lacking on this relationship as well as on the proportionality of energy required and mass to be vibrated.

The mechanical principle involved in most vibratory appliances so far developed in this country is that of an unbalanced revolving weight.

Vibration as now practiced may be divided into five kinds as to method:

1. Vibration of forms.
2. Internal vibration.
3. Vibration of reinforcement, structural steel members, or track assemblies.
4. Platform vibration.
5. Unit vibration.

Vibration of Forms

Vibration of forms is accomplished by attaching the vibrating element to the forms or applying it to the forms through the medium of a spud to which the vibrator is attached. In this latter case, the result may be a combination of form and internal vibration if the rigid unit reaches the forms through the concrete.

Vibration of forms has a special field of use where the space inside the forms is inaccessible for other methods, such as the ships above referred to, tunnel and sewer linings, horizontal structural members, long columns and the like. It has been very successfully used in embedding or encasing structural steel shapes.

For structures of large mass the economic advantage of form vibration may depend upon the additional cost of the extra strength of forms required and its effectiveness will depend upon the depth to which the pulsations are transmitted.

Internal Vibration

Internal vibration is accomplished by either attaching the vibrator to a member that is inserted into the fresh concrete, or by inserting the vibrator itself.

The use of internal vibrators is, of course, confined to form space that is accessible. When the vibrating element reaches the forms through the concrete, it combines form vibration with internal vibration. If the member is small and heavily reinforced the reinforcement may also be vibrated. Internal vibration is adapted to placement in both large and small masses.

Vibration of Reinforcement

Vibration of reinforcement is accomplished by transmitting impulses by direct contact with the vibrating element or through the medium of a spud to which the vibrator is attached. In the case of structural shapes, the vibratory element may be attached positively to the structural members. A recent example of the latter is the embedment in cinder concrete of the structural shapes of the new Post Office building in Philadelphia. Vibration of assemblies of parts, as in embedment of car tracks, is accomplished by attaching the pulsating element to the rails.

Vibration of reinforcement may result from vibration of forms supporting the reinforcement, or from internal vibration. Embedment of structural steel shapes by direct vibration of them may be supplemented by internal vibration and/or vibration of forms.

Platform Vibration

Platform vibration consists in applying the vibratory impulses to a plank or platform placed on the surface of the fresh concrete. It is especially adapted to vibrating

the surface of concrete in large form spaces, and has been very successfully used in the construction of concrete dams. Internal vibration may be combined with platform vibration.

Unit Vibration

Unit vibration consists in the vibration of an entire unit and usually includes a Vibrating Table carrying the units in molds. It is especially adapted to the manufacture of concrete products, and has been successfully employed in making units weighing even more than one ton.

Advantages

The advantages obtainable through the intelligent use of vibratory placement of concrete are:

1. Placement in forms where access for puddling or working by hand cannot be had, thus obviating the use of a mix of undesirable fluidity.
2. Economy in cement at a given water ratio, or a lower water ratio with a given amount of cement per unit of concrete.
3. Complete embedment of reinforcement—elimination of water and/or air filled voids under reinforcement or parts thereof.
4. Likelihood of economy in cost of placement.

Disadvantages and Precautions

Some of the precautions to be observed with, and limitations resulting from vibratory placement, are:

1. Vibration of forms requires that the forms be stronger than necessary for hand placement.
2. The forms should be tight when vibrators are used on them. The action of vibrators promotes leakage.
3. While vibratory placement permits the use of drier mixes than hand placement, there is a limit beyond which honeycombing will result, but mixes unworkable by hand placement may become plastic with vibratory placement. The job conditions must govern.
4. Internal vibrators in the drier mixes should be withdrawn slowly.
5. There is a limit to mass thickness that can be effectively and economically pulsated by attaching the vibrators to the forms.
6. The amount of power necessary for proper vibration is a function of the mass to be vibrated. The energy applied must be sufficient to preserve mobility in the mass.
7. The laws governing strength and durability as affected by the water ratio and curing are not abrogated by vibratory placement. Lower cement factors may be used and increased density expected, but proper curing is just as essential as with any other placement method. Vibration must not be expected to cure segregation.
8. Experience does not show that any of the various methods of vibratory placement or combinations of them can be depended upon to eliminate air bubbles from the surface or mass of the concrete nor surface "sand streaking."
9. Long continued vibration will have no harmful effect where the consistencies and mixes best suited to vibratory placement are used. Under such conditions, *under* rather than *over,* vibration is to be feared and the length of time of

vibration may well be limited only by the progress of placement required by job conditions. With wetter consistencies and higher mortar content than necessary for vibratory placement, long time vibration may produce undesirable mortar segregation and should be avoided.

The suggested range in time of vibration is from 15 seconds for concrete of wet consistency to one minute for concrete of dry consistency, the actual time depending on the action of the concrete of the consistency used as affected by the type of vibrator applied.

10. The proper position of form vibrators with respect to the surface of the concrete must be judged by the observable effect on the concrete. The vibrator should not be so far below the surface as to greatly minimize its effect in producing mobility.

Rapid increase in the use of vibratory methods and in the development of vibratory apparatus is to be expected. Vibration in the placement of concrete, properly applied, will in many cases yield better results than hand placement.

SELECTED BIBLIOGRAPHY ON HIGH-FREQUENCY VIBRATION OF CONCRETE

Concrete Ships Constructed by U.S. Shipping Board, by Walter R. Harper. Proceedings, American Concrete Institute, 1922, Vol. 18, page 83.

The intricate mass of reinforcing steel made tamping or settling concrete around steel without leaving voids of great importance. Concrete was placed through panels from the inside. The forms were then vibrated using pneumatic hammers on the inside of outside form working through these openings also on the inside form. Inserted in hammer was steel bar with end upset. Concrete observed to move 15 ft. from point of application. Vibration proved very successful.

Large-Span Reinforced Concrete Bridges. Concrete and Constructional Engineering, June, 1931, Vol. 26, No. 6, page 385.

A study of views of M. Freyssinet, designer and builder of Elorn–Plougastel Bridge having reinforced concrete arch spans of 590 ft. By use of vibration or similar action to increase density of concrete and incidentally to reduce the high local internal stresses which would result from presence of minute cavities between the constituent parts of the concrete, it has become possible in manufacture of pre-cast concrete members, such as posts, poles, etc., to obtain crushing strength of 14,000 p.s.i. Pneumatic vibration was therefore used in placing concrete in these arches.

Concreting the Calderwood Tunnel, by W. R. Johnson. Proceedings, American Concrete Institute, 1931, Vol. 27, page 1189.

Tunnel 26 ft. wide with 11 ft. high sides and semi-circular crown of 13 ft. radius. Lining is 12 inches thick. Two electric vibrators attached to forms, one on either side and operated intermittently during placing.

Precise Concrete Control at Koon Dam. Engineering News–Record, December 31, 1931, Vol. 107, No. 27, page 1024.

Thomas W. Koon Dam, 12 miles north of Cumberland, Md., built with very harsh mix of concrete using electric vibrators mounted on heavy plank and operated by three men who stood on plank during operation. Maximum size aggregate 6½ in. Exceptionally smooth surface free from honeycomb was secured.

The Effect of Materials and Methods of Placing on the Strength and Other Properties of Concrete Bridge Floor Slabs, by L. W. Teller and G. W. Davis. Public Roads, December, 1931, Vol. 12, No. 10, page 237.

Cooperative investigation by Port of New York Authority and U.S. Bureau of Public Roads. Gravel, limestone and Haydite used for coarse aggregate, sand and Haydite for fine aggregate. Concrete placed by hand, by Vibrolithic process and by vibration with electric vibrator and air hammer. Latter two were of spud type. Concrete placed by vibrating methods had higher flexural and compressive strengths than hand placed concrete. Pull-out tests showed better bond resulted from vibrated methods, the improvement being greater for deformed bars than for plain bars. Absorption less

for vibrated specimens and unit weight higher. Surface hardness reduced by vibration probably due to water coming to surface bringing with it finer materials.

Formwork and Concreting Methods on Monolithic Sewer, by Harold L. Andrus. Concrete, March, 1932, Vol. 40, No. 3, page 12.

3435 ft. of 54 in. circular monolithic concrete sewer was built at Kalamazoo, Mich., in 1931. Forms were lined with wood fibre board to produce smooth surface. Sewer built in 112 ft. sections. Six electric vibrators were used, operated by gasoline-driven generator. Vibrators clamped at 8 ft. intervals to upper segment of circular form on inside. A very impervious concrete was obtained with 1:2:3 mix, 5½ gal. water per sack of cement, about 2½ in. slump and there were a minimum of water pockets and honeycomb spots. Expresses opinion that concrete could not have been placed around this form without vibrators.

The Segregation of Water in Concrete Placed in Deep Forms, by F. H. Jackson and W. F. Kellermann. Public Roads, June, 1932, Vol. 13, No. 4, page 64.

Tests made by Bureau of Public Roads by placing concrete in columns 8 by 48 in. ranging in height from 3 to 12 ft. Samples of concrete taken through port holes in sides of forms. Some of these analyzed and others used for making cylinders. Cores also taken. Electric vibrators were attached to forms by clamping them to 2 × 4 inch battens. No serious segregation of concrete or water gain took place in concretes ranging in slump from 2 to 8 in. Factors that may have contributed to this were forms only 8 inches wide and relatively fine sand used. Placing by vibration produced about same average strength and uniformity as spading. A combination of spading and vibration appeared to increase strength beyond that obtained by either spading or vibration alone.

Stronger Concrete Pavement by Rapid Tamping, by C. E. Myers. Engineering News–Record, June 23, 1932, Vol. 108, No. 25, page 894.

Electric vibrator operated at about 3,500 r.p.m. was applied to strike-off board on track construction in Philadelphia. Concrete flowed down between ties, under bottom flanges of rails and against webs. Surface required no hand finishing. Cores showed dense concrete and high strength. Economy in labor also obtained on highway construction.

Compaction of Concrete Through the Use of Vibratory Tampers, by Raymond E. Davis and Harmer E. Davis. Journal, American Concrete Institute, June, 1933, Vol. 4, No. 9, page 365.

Vibrated Concrete, by T. C. Powers. Journal, American Concrete Institute, June, 1933, Vol. 4, No. 9, page 373.

Vibration imparts no new properties to concrete, the benefits result from ability to handle concrete of lower water content. Tests made in Portland Cement Association Laboratory show that, just as for hand-placed concrete, the quality of cement paste is chief factor determining strength, in both compression and flexure. Mortars have higher strength than concretes (at a given value of cement-voids ratio), especially in rich mixes when tested in flexure. Prolonged vibration increased strength of dry mixes slightly and reduced strength of wet mixes, maximum reduction being 10 per cent. These variables are of minor practical importance. Vibrated specimens have withstood 110 cycles of freezing and thawing without showing signs of trouble, indicating no impairment in resistance to weathering. Unlike hand-placed concrete, lower limit of sand factor in vibrated concrete is not indicated by strength tests but must be determined by behavior. Mixture must be plastic or become plastic under vibration. Water content may be reduced by 8 or 0 gal. per cu. yd. of concrete. Shrinkage tests not made but above reduction indicates shrinkage may be reduced nearly one-half that for comparable hand-placed concrete.

High Frequency Vibratory Machines for Concrete Placement, by M. I. McCarty. Journal, American Concrete Institute, September–October, 1933, Vol. 5, No. 1, page 49.

Discusses types of vibrators for different classes of work and mechanical requirements of electric vibrators. Frequencies between 4000 and 4500 r.p.m. efficient. Types of equipment used on different jobs including screed for placing grid decks.

Placement of Concrete by Mechanical Vibration, by A. W. Munsell. Journal, American Concrete Institute, September–October, 1933, Vol. 5, No. 1, page 54.

Discusses practical applications and time of application with relation to size of section. A few tests in laboratory of New York Port Authority indicated that mechanical vibration increased weight of concrete from 5 to 10 per cent. Expresses opinion that vibration should be made to pay for itself by minimizing patching and rubbing costs rather than by economizing on cement.

Fabricating 36-inch Reinforced Concrete-Steel Cylinder Water Mains, by J. F. Brett. Journal, American Concrete Institute, September–October, 1933, Vol. 5, No. 1, page 61.

Montreal Water Board installing 60,000 ft. of concrete pipe consisting of outside shell 2¼ in. thick placed by vibration and inside shell 1¼ in. thick placed by centrifugation. Pipes are 16½ ft. long and weigh 5 tons each. Specifications call for compressive strength of 4500 p.s.i. at 28 days. Pipes cast vertically in steel molds with 4 vibrators attached which are kept going continuously while concrete is being placed which is also continuously. Mix 1:1.6:1.9 with 35 lb. water per cu. ft. of cement gives strengths from 5,600 to 6,500 p.s.i. at 28 days. Vibrators now used on all work. Slump should be less than 2 in. on bridge and similar construction. An excess of paste tends to hold air bubbles.

Vibration in Making Roof Deck Slabs, by A. B. Shenk. Journal, American Concrete Institute, September–October, 1933, Vol. 5, No. 1, page 63.

Precast concrete slabs for roof decks are made in steel molds. Two pneumatic vibrators are attached to under side of mold producing a satisfactory finish with a lower water-cement ratio. Seemingly the greater the amplitude the more rapidly the concrete flows into position. Greater speed seems to produce slower movement but with a corresponding increase in density. Proper balance for this work found to be about 2000 vibrations per min.

Section 2

CENTRAL MIXED AND TRANSIT MIXED CONCRETE

Within the last few years large investments have been made in central plants for the assembly of materials and the batching, mixing and distribution of concrete to construction jobs over wide areas. At first there was well grounded objection to the output of such plants due to the compacting and segregation of concrete transported for considerable distance in ordinary truck bodies. This objection was met by the development, first of "agitator" trucks and later, truck mixers furnished with devices to control the introduction of water, the time of mixing, etc.

These central plants introduce various complications in the tasks of Engineers, Inspectors and Contractors concerned with their product. Some of the advantages and disadvantages of this Industry may be listed as follows:

Central Mixed Concrete—Advantages

The chief advantage of a central mixing plant on the manufacturing side is that a permanent location and comparatively large output justify the installation of adequate facilities for the proper storage and classification of aggregates, for accurate batching by weight, and for regulation of temperature and control of water-cement ratio. Good water supply is also available.

Most up-to-date plants employ agitator trucks to transport the mixed concrete from the central mixing plant to the job.

These agitator trucks should insure the transportation of concrete over long distance without segregation of the materials and promote easy discharge of concrete in good condition for use on the job.

The advantages to the purchaser include:

(a) Saving of storage and care of materials. This is a real advantage on many small railroad jobs where space is limited, and often eliminates the necessity for a construction track at the job, thus contributing to economy.

(b) The concrete plant including mixer and appurtenances are dispensed with.

(c) Labor costs are reduced as it is no longer necessary to keep a concrete gang "standing by" waiting for concreting operations.

Disadvantages

(a) Difficulty of proper inspection. On the smaller railroad jobs, it is expensive to furnish an inspector at the central plant in addition to the man at the job, the result being that otherwise entire reliance must be placed in the operator at the central plant to proportion and manufacture the concrete according to instructions. Also, if poor concrete arrives on the job, it is impossible to correct conditions promptly as there may be several truck loads in transit.

(b) Possibility of breakdown of truck or delay due to traffic, etc.

(c) Difficulty in connection with special placing equipment such as elevating requirement.

(d) If the purchaser furnishes his own bin tested cement, various difficulties are encountered to insure check of shipments, and segregation of the owner's cement for use in his work.

(e) Depending on the distance of the job from the central plant, delays and irregularities in delivery may increase costs or cause disorganization on the work.

Transit Mixed Concrete

Prior to the introduction of transit mixers, concrete mixers were fairly well standardized and the relationship of capacity to diameter of drum and peripheral speed had been established within certain limits. The introduction of mixer trucks of various designs raises a question as to their relative merits.

In general, it is recommended that the transit mixers should be of cylindrical form with the barrel of a diameter large in proportion to its length, and with the mixing mechanism driven by an engine independent of the truck motor. Some manufacturers do not recommend truck mixers of over 3½ cy. capacity.

The considerations listed as to the advantages and disadvantages of central mixed concrete apply to a considerable extent to transit mixed concrete and in addition, the following should be noted:

Advantages

The batched materials may be held in the truck mixer until a predetermined point enroute and water added and mixing started then, or the mixing process may be deferred until the truck is at the job and mixing can be done under the supervision of the inspector. In this case, only the batching is done off the job.

In general, the equipment of mixer trucks employed by responsible distributors consists of relatively costly units which are well serviced and maintained by garage mechanics, and are therefore, apt to be in better physical and mechanical condition than the ordinary run of mixers in use. It is entirely feasible to inspect these trucks and their operation before approving their use on any particular job, and instructions should be issued accordingly.

Disadvantages

It has happened in individual cases, that obsolete or substitute trucks have been put in service or the order switched to another outfit not properly equipped for the service specified. A serious difficulty in the purchase of concrete mixed in transit is the disposition of batches which should be rejected after delivery. It is probably impossible to eliminate occasional mistakes in batching, which may be due to confusion in orders, or in the amount of water or other defects resulting in batches which should be wasted if delivered by a mixer truck. These difficulties can be anticipated or corrected by an inspector when the entire operation of manufacture is under observation and control on the ground.

Specifications

Reference is made to proposed Tentative Specifications for Ready Mixed Concrete—A.S.T.M. C–33 T. In this specification, under Composition of Concrete, a broad approach to the subject is made when the following methods of proportioning are described:

(8) By volume
(9) By weight
(10) In terms of quantity of cement
(11) Based on water-cement ratio
(12) Based on strength

Under the heading of mixing are two sections which apparently place the entire responsibility for the results of the mixing operations on the manufacturers of the equipment leaving to the customers, Engineers or Inspector very little discretion under the specifications, viz:

(19) Central Mixed Plant.—In the case of the stationary mixers the mixer drum shall be of adequate size to accommodate the maximum batch, and shall be in accordance with the Concrete Mixer Standards adopted by the Mixer Manufacturers' Bureau of the Associated General Contractors of America. The mixer shall be rotated at the rate recommended by its manufacturer.

(20) Truck Mixing.—In the case of truck mixers, the size of batch shall not exceed the rated capacity of the mixer as stated by the manufacturer and as stamped in metal at a prominent place on the mixer. The mixer shall be water-tight when closed. Each batch of concrete shall be mixed not less than 50 nor more than 150 revolutions of the mixer at the rate of rotation specified by the manufacturer as mixing speed. Any additional mixing shall be done at a slower speed specified by the manufacturer for agitation.

Doubtless the manufacturers' opinions as to the capacity, speed, and conditions of operating their equipment are based on tests and experience with average conditions, but variations in the comparative weights of aggregates, conditions as modified by low temperatures or long hauls, and the methods of deposit in the forms may modify the mixing requirements considerably and should be given consideration in any general specification for Ready Mixed Concrete.

Section 3

SEGREGATION

There are three kinds of segregation:

(1) Segregation in parts of structures of materials in a finely divided state or of low specific gravity. This type of segregation is induced by the flowing action of wet concrete within the forms and the washing action in extremely wet mixes. The materials thus separated out are segregated in horizontal laitance seams or are incorporated in considerable quantity in the concrete in parts of the structures. Such concrete and laitance seams have low resistance to weathering and particularly to freezing. Excepting when concrete is deposited in water, this type of segregation is always associated with wet mixes, and its prevention lies in maintaining a safe-working consistency. When concrete is deposited in water, the buckets or tremies must be so designed and so manipulated as to minimize the flow and wash.

(2) Segregation of water and its incorporation in concrete in parts of structures in quantity in excess of that designed for the mix, results from the tendency of water to move upward through the concrete while in a plastic state. This movement, result-

ing in what is termed water gain, may, unless corrected or controlled, result in a water-cement ratio too high for durability under severe exposure. This type of segregation is difficult to control or minimize.

The most essential basic requirement for the control of water gain is the securing of a high degree of workability and the maintaining of a suitable consistency. In this connection, refer to the report of this committee, published in the 1932 Proceedings, and in Bulletin 344, where mention is made of the need, at times, for correction or control of water gain by placing concrete of dry consistency to absorb some of the rising water, and of adequate provision in specifications to provide for this.

(3) Separation of mortar from coarse aggregates in concrete of safe-working consistency may be due to faulty type or condition of the mixer, the discharge from the mixer, the conveying, whether by barrow, belt, buggy, bucket, chute or truck, the discharge into the forms, or to the manipulation within the forms. This type of segregation makes more difficult the puddling or compacting of concrete without honeycombing or stone pockets, especially in reinforced concrete where it is necessary to protect reinforcement from corrosion.

This type of segregation can be detected by visual inspection of the concrete as it is being levelled to place in the forms. Investigation of the manipulation of the concrete in its mixing, conveying, depositing and compacting should reveal the cause or causes and suggest the remedy insofar as manipulation of the mixed concrete is involved. It should be borne in mind, however, that a basic requirement, in obviating this type of segregation is the maintaining of a high degree of workability at the driest consistency appropriate for the type of structure and method of compacting.

Workability and Consistency

The right way to obtain workability of the concrete suitable to the method of compacting, is through the proper design of the mix, with respect to the size, quantity and grading of the aggregates. Of special concern is the relative proportions of sand and coarse aggregates and the grading of the sand. The first can be determined by trial batching. Probably the most significant factor in graded sand is the percentage passing the No. 48 (or No. 50) sieve. 15 per cent is preferable, although 10 per cent is the minimum allowable.

Failing this requirement, the sand may well be rejected or sufficient fines either in the form of fine sand, added cement, or an admixture, subject to the approval of the Engineer, may be added to compensate for deficiences in fines.

It should be borne in mind that a high degree of workability in concrete gives it those characteristics which permit of easier placement at a less liquid consistency and, for compacting by puddling, a stiff, sticky consistency, which tends to hold the aggregates together in the mass, can usually be maintained. The factors contributing to better workability tend also to stabilize the water in the concrete when in a plastic state, thus tending to minimize water gain. For example, when pronounced sand streaking occurs along the forms, the remedy usually lies in increasing the fines in the sand and the use of a less liquid consistency. When the sand streaking occurs to a pronounced degree, then water gain will be pronounced until corrected or controlled.

A high degree of workability and the maintenance of a stiff consistency will tend to stabilize water in the concrete, minimize water gain and therefore sand streaking as well as entrapment of water under the coarse aggregate.

Appendix C

(5) FOUNDATIONS

D. B. Rush, Chairman, Sub-Committee; M. F. Clements, W. F. Cummings, G. F. Eberly, G. R. Smiley, A. W. Smith, I. F. Stern, G. E. Tebbetts, Jamison Vawter, C. C. Williams, J. J. Yates.

GENERAL SPECIFICATIONS FOR FOUNDATIONS OF RAILWAY STRUCTURES

1. Definitions

FOUNDATION.—The natural material which supports the structure, and its loads, whether strengthened or not by the use of piles or other means to secure adequate bearing.

"SUBSTRUCTURE" refers to that part of the structure which supports the superstructure and its loads.

These definitions are presented for adoption for printing in the Manual.

2. Drawings

After the contract has been awarded and before any work is commenced, the Contractor shall submit to the Engineer for approval duplicate prints of drawings which supplement the detail plans of the Company, showing the proposed methods of doing the work and details of construction work proposed. The tracings of these drawings or other reproducing prints shall be the property of, and be delivered to the Company after the completion of the contract. These drawings shall be twenty-four (24) by thirty-six (36) inches in size, including margins. The margin at the left end shall be one and one-half (1½) inches wide and the others one-half (½) inch. The title shall be in the lower right-hand corner. No changes shall be made on any approved drawing without the consent, in writing, of the Engineer. The Contractor shall be responsible for the correctness of his drawings, although the drawings may have been approved by the Engineer.

3. Excavation

All excavation shall be made to permit the placing of the substructure. The Contractor shall maintain the excavation in a safe condition during the construction period.

4. Open Construction—With Sheeting

Where it is necessary to retain the earth, the sides of the excavation shall be held by sheeting. Sheeting if tight may be used as a form for concrete to the top of the lowest footing course and may be left in place at the option of the Contractor, but if so left, it shall be cut off at the ground without extra cost to the Company.

5. Cofferdams, Cribs, Open Caissons, etc.

Where it is necessary to make excavation in water, a suitable cofferdam, crib, open caisson or similar type of construction shall be used to exclude the water, in order to permit the excavation of the material above the foundation, so that the substructure may be placed directly upon it. The Contractor may select his own type of construction, subject to the approval of the Engineer.

6. Excavation Materials Classified

(a) Classification of Materials

(A) Rock shall include all rock occurring in masses of one cubic yard or more in volume or in strata exceeding six inches in thickness which require blasting for economical removal.

(B) Common shall include all material other than rock.

(C) Slope Excavation shall include all material excavated without the use of sheeting and bracing, and which has natural earth slopes at the sides of the excavation.

(D) Pit Excavation shall include all material excavated in a pit having the sides retained by sheeting and bracing. Where slope excavation and pit excavation are required for the same foundation, the dividing plane between them shall be the average ground elevation at the sides of the pit.

(E) Dry Excavation shall include all material removed during the excavation period, from above that elevation at which the pit can be kept sufficiently clear of water by ditching or by the continuous service of one man using a four-inch hand-operated diaphragm pump to permit the excavation to be done.

(F) Wet Excavation shall include all material removed during the excavation period, from below that elevation at which the pit can be kept sufficiently clear of water by ditching or by the continuous service of one man using a four-inch hand-operated diaphragm pump to permit the excavation to be done.

(b) Classification of Work

(1) Dry Excavation
- (a) Dry rock excavation.
- (b) Dry common slope excavation.
- (c) Dry common pit excavation.

(2) Wet Excavation
- (a) Wet rock excavation.
- (b) Wet common excavation.

7. Disposal of Surplus Material and Backfill

If the Engineer considers the surplus excavated material suitable, it shall be used for backfilling foundation pits to the original ground line and surplus material not so used will be disposed of as the Engineer may direct.

8. Preparing Natural Earth Foundation

The material upon which the substructure is to be placed shall be excavated to the outline of the footing course, as shown on the plans, or as established by the Engineer, and shall be of sufficient size to permit the placing of the full width and length of the footing shown with full bed. Excavation which causes rounded or undercut corners and edges of footings will not be permitted. The elevations of the bottoms of footings, as shown on the plans, shall be considered as approximate only and the Engineer may order, in writing, such changes in dimensions or elevations of footings as may be necessary to secure a satisfactory foundation. When the foundation bed is solid rock, all loose or disintegrated portions of the rock shall be removed. Sloping surfaces shall be cut to a level, or to stepped level planes. All open fissures in rock foundation beds shall be filled with concrete before the substructure is started.

9. Removal of Water from the Excavation Pit

In the open cofferdam method, the cofferdam shall be made of such materials as to provide a pit, the sides of which are practically impervious to water. Suitable hand or power-driven pumps shall be provided to remove the water, so that workmen may enter the pit and remove the excavation material in a practical and economical manner. If the materials underlying the foundation are porous to the extent that it is impracticable

to remove the water by pumping, the Engineer may direct that the excavation material be later removed by dredging and the foundation be prepared without removing the water. Under these conditions, after the excavation has been completed to the satisfaction of the Engineer, a concrete seal shall be placed by depositing concrete through water, in accordance with A.R.E.A. Manual, page 573. The seal may be considered a portion of the foundation or of the substructure, as stated in the agreement. The thickness of the seal shall be sufficient to overcome hydrastatic pressure on the structure of which it becomes a part.

Where a depth of water is encountered in the cofferdam that will result in the creation of a head under the footing course, provision shall be made in the construction of the cofferdam to provide sufficient space between the inside of the cofferdam and the substructure forms to permit of drain to a sump.

Pumping shall be from a sump separated from green concrete to avoid wash of concrete materials. Pumping to unwater sealed cofferdam shall not be commenced until the concrete has had a set sufficient to overcome hydrostatic pressure.

10. Strengthening the Foundation Material with Piles

In general, the detail plans will show the foundation piles required. If they are not provided for and the Engineer, after an examination of the foundation, considers the earth has insufficient bearing value to support the structure, he shall direct that it be strengthened by the use of foundation piles or by other means. The excavation shall be cleaned of any loose or displaced material and débris before and after the foundation piles are driven and before the substructure is placed.

The Contractor shall submit full details as to the method and equipment he proposes to use in the driving and cutting off of the piles and shall secure the approval of the Engineer before any work is started.

11. Foundation Piles

Foundation piles shall be timber, concrete, steel, or a combination as shown on the plans approved by the Engineer.

(a) Timber piles may be treated or untreated. They shall be in accordance with the A.R.E.A. Specifications for First or Second-Class Piles as required. If treated piles are used the treatment shall be in accordance with the A.R.E.A. Specifications for the Preservative Treatment of Wood. They shall be treated unless submerged at all times.

(b) Concrete piles may be "Cast-in-Place" or "Precast". The Contractor shall submit plans and specifications for the type of pile he proposes to furnish and must secure the written approval of the Engineer before work is commenced.

(c) Steel piles shall be manufactured from copper-bearing structural grade of steel, as shown on the plans, approved by the Engineer.

(d) Combination piles shall be manufactured according to plans approved by the Engineer.

12. Pile Driving

Pile driving shall be in accordance with the A.R.E.A. "Pile Driving Principles of Practice" and also in accordance with the following:

The Engineer shall instruct the Contractor in the work to be done and will approve and direct that the piles shall be driven to true location and proper elevation, within the tolerances specified on the plans. Piles injured in driving, or driven out of place, shall be replaced by other piles. A pile driven too low to be cut off at the proper elevation shall be replaced. A pile damaged in driving and unfit for the place in which it is driven shall be replaced or repaired. A pile forced up due to the driving of surrounding piles shall be redriven. Piles shall be cut off level to proper elevation.

13. Measurement and Basis of Payment

The unit of measurement will be according to legal standards of weights and measurements.

The work to be paid for shall be determined by the Engineer from the original plan dimensions, or as altered by him, applying the unit rates to the quantities so determined. The Contractor will be paid on the basis of the original summation of his proposal, adjusted for the additions and reductions in quantities based on his unit prices for such changes in quantities.

Measurement for payment shall be as follows:

(a) Foundation excavation (unit = cubic yard). The price per cubic yard shall include the removal of all material encountered above the foundation and the backfilling of foundation pits around completed masonry, using surplus excavated material, as follows:

(A) The volume of Dry Excavation, slope methods, shall be obtained from the actual measurement of all material removed in slope excavation, exclusive of any material measured by the pit method.

(B) The volume of Dry Pit Excavation shall be the volume of a prism bounded by vertical planes at one foot outside of the footing course, exclusive of any material measured in slope excavation and exclusive of any material included in the wet excavation prism.

(C) The volume of Wet Excavation shall be the volume of a prism bounded by vertical planes at one foot outside of the footing course and between the horizontal planes at the water level defined in paragraph No. 6, Section F, and the average elevation of the excavated foundation.

(b) Backfill, new material (unit = cubic yard in place). The price per cubic yard for new material other than that from excavation placed in backfill shall cover the cost of supplying in place the required new material for such backfill.

(c) Piles delivered (unit = linear foot). The prices per linear foot for untreated timber and treated timber, premoulded precast concrete, steel and combination piles, shall include the supply, delivery and unloading at the site, of piles in number and lengths as approved by the Engineer.

(d) Pile driving (unit = linear foot). The price per linear foot shall include all work of any kind in connection with the driving, including the cutting off. The price will be applied to the net linear feet of piles left in the finished structure.

(e) Pile Shoes (unit = each). The price each covers the pile shoes actually placed.

(f) Cast-in-Place Concrete Piles (unit = linear foot). The price per linear foot shall cover in full the total cost of piles cast-in-place. The price will be applied to the total length of piles in place in the finished structure.

Appendix D

(6) TENTATIVE SPECIFICATIONS FOR LINING RAILWAY TUNNELS WITH CONCRETE

G. F. Eberly, Chairman, Sub-Committee; G. E. Boyd, Kennerley Bryan, Jr., M. F. Clements, Maurice Coburn, W. F. Cummings, O. V. Parsons, I. L. Pyle, G. R. Smiley, H. H. Temple, C. A. Whipple, D. E. Woozley.

GENERAL

Scope

1. These specifications cover the lining of new tunnels and the relining of old tunnels through ordinary formations which involve no special features.

(II) DESIGN

Interior Dimensions

2. The interior dimensions shall not be less than those shown as standard for single and double track tunnels in the American Railway Engineering Association's Specifications for Roadway (Fig. 1).

Footings

3. Where footings are required they shall be at least 2 ft. 0 in. in depth and as much more as necessary to secure a good foundation. The footings shall be at least 2 ft. 0 in. in width and the top shall be at the elevation of sub-grade. The face of the footings shall be in the same vertical plane as the face of the sidewalls (Fig. 1). Each section of footing shall be substantially keyed to each adjacent section.

Floor and Ballast Walls

4. If considered desirable, a concrete floor and ballast walls shall be installed. The floor shall be at least 6 in. thick and shall slope ½-inch in 12 in. from the center line of the tunnel at the elevation of the sub-grade towards the sidewalls. The ballast wall, with the toe of the wall at least 12 in. from the face of the sidewall and the top not more than 3 in. below the top of the tie, shall be 12 in. wide at the top and 24 in. at the bottom (Fig. 1).

Sidewalls

5 (a). The sidewalls shall be at least 2 ft. 0 in. thick, when no temporary supporting of the face of the excavation is required. The space between the face of the sidewall form and the face of the excavation shall be entirely filled with concrete, except that durable rock may be substituted for concrete to fill large holes back of the normal line of excavation. If rock is used it shall be rammed into place (Fig. 1).

(b) If temporary supporting of the face of the excavation is required, the space between the lagging and the face of the excavation shall be firmly packed with durable rock, rammed into place. The space between the face of the sidewall form and the lagging shall be entirely filled with concrete with a minimum thickness of 18 in. in front of the temporary supports (Fig. 1).

Each section of sidewall shall be substantially keyed to each adjacent section.

Arch

6 (a). The arch shall be at least 2 ft. 0 in. thick when no temporary supporting of the face of the excavation is required. The space between the face of the arch forms and the face of the excavation shall be entirely filled with concrete (Fig. 1).

(b) If temporary supporting of the face of the excavation is required, the space between the lagging and the face of the excavation shall be firmly packed with durable stone, rammed into place. The space between the face of the arch form and the lagging shall be entirely filled with concrete with a minimum thickness of 18 in. in front of the temporary supports (Fig. 1).

Refuge Niches

7. The refuge niches shall be 18 in. deep, 4 ft. 0 in. wide and 7 ft. 0 in. high. They should be spaced 100 ft. apart on each sidewall, and staggered so that the niches on opposite walls shall be 50 ft. apart. The bottom of the niches shall be at the elevation of the bottom of the track tie.

Drainage Openings

8. Vertical and diagonal openings or tile drains shall be installed in the rear of the concrete lining with outlets through the sidewalls to provide ample drainage where water is encountered. The outer end of outlets shall be 6 in. above the bottom of the gutter. Sub-drains shall be provided under the concrete floor where water is encountered. Sufficient tile shall be installed in the ballast walls to provide drainage for section of floor between ballast walls.

(III) CONCRETE

Specifications

9. The specifications for Portland Cement Concrete, Plain and Reinforced, of the American Railway Engineering Association, shall be used in the manufacture and placing of the concrete, together with the additional provisions given herewith.

Proportioning

10. The concrete shall contain not to exceed 5.5 gallons of water per sack of cement and have a minimum compressive strength of 3,000 lb. per square inch, in 28 days.

(IV) FORMS

Length

11. The length of forms for continuous placement of concrete between construction joints shall be limited by the ability of the placement method to get a complete and homogenous filling of the space behind the forms, but in no instance shall the length be more than 40 ft.

Removal of Forms

12. The forms shall not be removed in less than 48 hours where the surrounding temperature is 70 deg. or over. When the temperature is below 70 deg., the time shall be lengthened as directed by the engineer.

(V) PLACING CONCRETE

Hand Placing

13. Concrete placed by hand shall be of such consistency that it can be thoroughly packed so as to entirely fill the forms. This consistency shall be obtained without varying the water-cement ratio.

Pneumatic Placing

14. Pneumatic placing of concrete shall be done with a concrete placing machine which blows the concrete through a pipe line with compressed air. The air pressure and the consistency of the concrete shall be so regulated, without varying the water-cement ratio, that the coarse aggregate shall not be blown away from the mortar matrix when the concrete issues from the end of the delivery pipe. Flexible pipe branches shall be provided, when necessary to deliver the concrete at approximately its final position in the lining. The concrete shall be shot into a metal baffle box surrounding the end of the delivery pipe, or the end of the delivery pipe shall be kept as close to the mass of concrete as conditions will permit, and at no time more than 5 ft. away, so as to prevent separation of the mass and permit continuous inspection.

Pumping

15. Placement by pumping shall be done with a plunger pump which forces the concrete through a pipe line by direct pumping action without using compressed air in the line. Concrete shall be pumped as nearly as possible to its final place of deposit, using flexible pipe branches where necessary.

Shotcrete

16. Placement of Shotcrete shall be done by building up a lining by shooting on the Shotcrete in thin layers with a pneumatic hopper machine in which the properly proportioned dry cement and sand are pneumatically mixed and forced through a hose to a nozzle attached to the end of the hose, where water under pressure shall be introduced into the dry mix just prior to being sprayed into place.

Order of Placing

17. If a floor is not installed, a section of footings, sidewalls and arch shall preferably be placed in one continuous operation.

When a floor is installed, the floor, ballast walls, footings and the lower 2 ft. of sidewalls should preferably be placed monolithically.

Compacting

18. Concrete, during and immediately after depositing, shall be thoroughly compacted, preferably by means of vibrators, which can be applied to or in the mass of concrete.

Laitance Seams and Bonding Surfaces

19. The consistency of the concrete and method of placement shall be such that no laitance seams are formed at fill planes. If so formed, they shall be completely removed and the forms and the progression of the work shall be such that this may be done. Concrete surfaces on which new concrete is to be deposited shall be thoroughly cleaned of all laitance, dirt and water before concrete is placed.

Drainage During Placing

20. Separate and distinct provision for drainage shall be made where necessary to prevent the placement of concrete in water or contact of the fresh concrete with moving water. Effective weeps and drains shall be provided where necessary to prevent hydraulic pressure against the lining until, in the opinion of the engineer, sufficient strength has been acquired to withstand the pressure.

Curing

21. After the forms are removed the surface of the tunnel lining shall be kept wet for a period of at least seven days.

(VI) CONSTRUCTION AND EXPANSION JOINTS

Construction Joints

22. No construction joints or fill planes shall be formed in such locations as to reduce the effectiveness of the lining in resisting pressure from the surrounding earth or rock.

Expansion Joints

23. No expansion joints shall be provided other than the construction joints. When necessary, non-corrosive water stops shall be installed at construction joints.

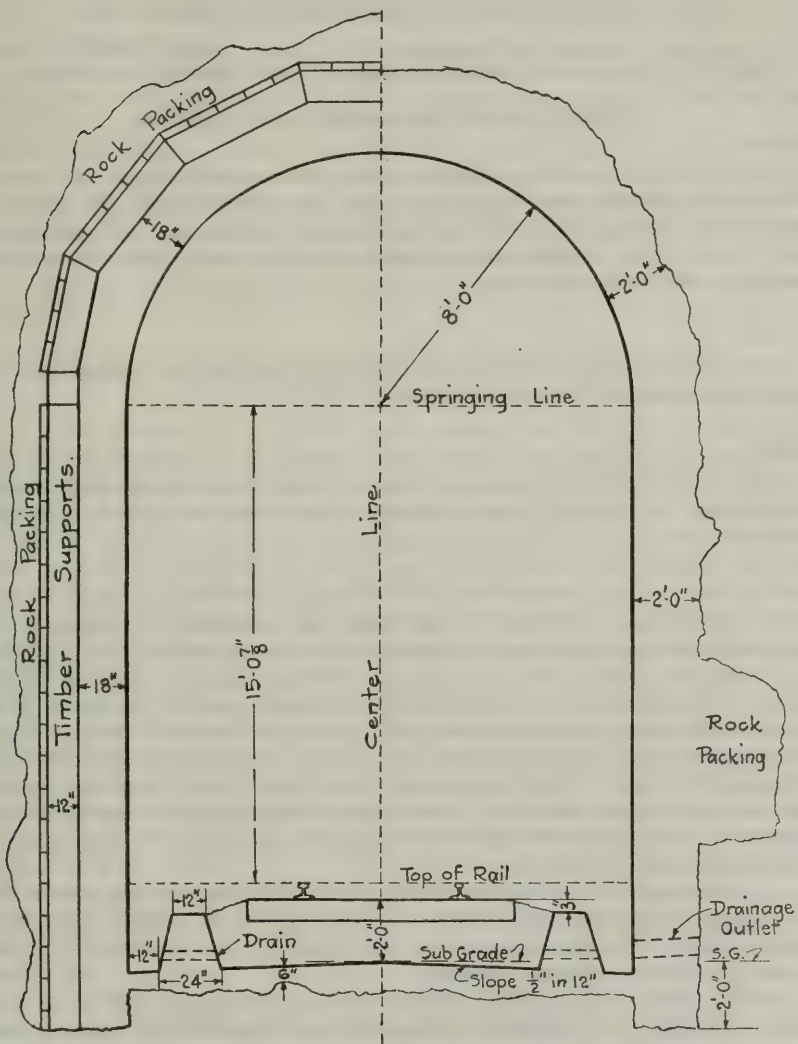


FIG. 1.
Concrete Lining.
Single Track-Tangent.

Appendix E

(7) PNEUMATICALLY PROJECTED CONCRETE

T. L. Condron, Chairman, Sub-Committee; G. E. Boyd, Kennerly Bryan, Jr., W. K. Hatt, A. C. Irwin, D. A. Ruhl, G. E. Tebbetts, H. H. Temple, L. W. Walter.

TENTATIVE SPECIFICATION FOR SHOTCRETE

NOTE A.

Shotcrete is here used as a brief descriptive term (not copyrighted) for a material consisting of Portland cement, sand and water placed pneumatically by means of a machine that discharges water and pre-mixed cement and sand, under regulated pressures, through pipes or hose, and a discharge nozzle, the water being combined with the cement and sand at the nozzle.

NOTE B.

Shotcrete machine is here used as a brief description term (not copyrighted) for a pneumatic machine used to place Shotcrete.

NOTE C.

All of the constituent materials of Shotcrete shall conform to the latest Standard Specifications for Portland Cement Concrete of the American Railway Engineering Association.

GENERAL

1. All Shotcrete work shall be done under the supervision of experienced foremen, using only experienced men as machine and nozzle operators.

2. Shotcrete shall consist of a mixture of Portland cement and sand, in the proportion of one bag of cement to three cubic feet of sand, placed by pneumatic pressure through a Shotcrete machine, with the proper amount of water for hydration applied in the mixing nozzle. The cement and sand shall be pre-mixed dry in a batch mixer and screened through a ¼-inch screen before being placed in the hopper of the Shotcrete machine. By the term "dry" is not meant that all moisture must be removed from the sand but that it shall have only the normal water content of bank sand, that is from 3 per cent to 8 per cent.

3. Water used in hydrating the material at the nozzle shall be clean and free from all substances that would interfere with the setting qualities or strength of the cement. Water pressure in the delivery pipe shall be maintained at 10 to 20 lb. per sq. in. above the air pressure in the Shotcrete machine.

4. The volume of air passing through the lower chamber of the Shotcrete machine, as measured by a suitable air meter, shall be that which will produce a nozzle velocity of from 375 to 500 feet per second when a ¾-inch diameter nozzle tip is used; 425 to 525 feet per second when a 1-inch diameter tip is used; and 475 to 550 feet per second when a 1¼-inch diameter tip is used. In case an air meter is not available, a uniform pressure of not less than 35 lb. per sq. in. shall be maintained in the placing machine. Where the length of the hose between the placing machine and the point of placement exceeds 100 feet horizontally and/or 25 feet vertically the pressure shall be increased so as to secure satisfactory velocity at the nozzle.

5. Shooting strips shall be employed to insure square corners, straight lines and proper thickness of Shotcrete. These shooting strips shall be so placed that they will not trap rebound.

6. When "shooting" any surface, the stream of flowing material from the nozzle shall impinge as nearly as possible at right angles to the surface being covered. All deposit of loose sand shall be removed prior to shotcreting. Should any such deposit be covered with Shotcrete, it shall be cut out and removed by the contractor without additional compensation.

7. After the main body of Shotcrete has been shot into place, high spots are to be removed with a sharp-edged screed or trowel in such a way as not to drag the Shotcrete surface. After this has been done and the shooting strips have been removed, the entire surface is to be given a flash coat of Shotcrete which is not to be troweled or screeded but may be brushed with a wet brush if a brush finish is desired.

8. The Shotcrete shall be kept wetted for at least four days after placing. No Shotcrete shall be placed when the temperature of the surrounding air is below 40 degrees Fahr., or against surfaces in which there remains any frost.

9. Measurement for all Shotcrete areas shall be the exposed surface area of the Shotcrete.

ADDITIONAL REQUIREMENTS FOR SHOTCRETE PROTECTION OF STRUCTURAL STEEL

10. Steel members to be protected with Shotcrete shall be cleaned thoroughly of all loose rust, scale, grease, dirt, paint or any other foreign material that will prevent proper adhesion between the Shotcrete and the steel. New steel members that are to be protected with Shotcrete should not be painted or oiled.

11. The Shotcrete encasement of steel members shall follow generally the outline of the members. It shall have a thickness of 1½-in. except at the underside and edges of lower flanges of floorbeams and girders where the thickness shall be 2 inches, placed in not less than two operations, with an interval of two to three hours between operations. The thickness specified is to be measured from the surface of the steel member and not from the tops of rivet heads.

12. Shotcrete used for the encasement of steel shall be reinforced with one layer of 2 in. × 2 in. — 12ga × 12ga or 3 in. × 3 in. — 10ga × 10ga galvanized electric welded wire fabric weighing not less than 37 lb. per 100 sq. ft. This reinforcing shall be cut in sheets and properly bent so that it may be spaced approximately ½-inch away from the surface of the steel members, and so that it will have a minimum coverage of ¾-inch of Shotcrete. Adjacent sheets of mesh shall be lapped one and a half meshes and securely wired together. On all built-up steel girders, I-sections and channels, holes shall be shop-punched through the webs of the members for tying the reinforcing mesh in place. On girders and I-s of more than 20 inches depth, two lines of holes shall be punched, or drilled, one line just below the top flange and one line just above the lower flange. These holes shall be not more than three feet apart in each line. Where the webs are over five feet in depth, an additional line or lines of holes shall be punched or drilled so that the horizontal lines shall not be more than 3 ft. 6 in. apart. Three-eighth-inch (⅜-inch) round rods shall be so held in place by wire ties through the holes in the webs, that the rods shall be at least ¼-inch clear of the webs, and the reinforcing mesh then securely wired outside of these bars with wire ties approximately 18 inches apart. Care shall be taken to prevent the mesh being drawn against the flanges of the steel members.

13. Instead of punched holes in webs, specified in paragraph 12 above, for use in attaching ⅜-inch round rods, suitable connecting pieces may be welded to the webs and the ⅜-inch round rods in turn welded to the connecting pieces if approved by the Engineer.

14. "Gunite", "Guncrete," or other similar materials commonly known by copyrighted names, if complying with these specifications, will be acceptable where Shotcrete is specified.

Action Recommended

This report is submitted as information with the recommendation that the subject be continued.

Appendix F

(8) DESIGN OF EXPANSION JOINTS INVOLVING MASONRY STRUCTURES

C. A. Whipple, Chairman, Sub-Committee; G. E. Boyd, M. Coburn, L. V. Haegert, J. A. Lahmer, W. M. Ray, G. E. Robinson, D. E. Woozley, W. K. Wyatt.

During the last two years the Committee collected from a number of carriers plans covering various types of joints involving masonry structures to meet various conditions, and last year submitted sketches appearing under Appendix E, Bulletin 353, page 599, as information.

This year the Committee has made further study of the joints submitted, with criticisms and suggestions of the various details, and offers the following basic principles to be observed in determining the details of expansion joints:

Primarily, expansion joints should permit volume change movements, without developing injuriously high local stresses.

Such movements include the shortening as well as lengthening of adjacent members, and repeated reversals of such movements.

Drainage, waterproofing, and traffic considerations complicate the design, but must not be allowed to cause violation of the purpose of such joints.

The simplest design effectively to meet conditions should be chosen. The possibility of changing service must be considered.

Expansion Joints may be classified as follows*:

(1) **Open Joints**

(a) Unrestrained motion—free drainage.
(b) Unrestrained motion—drainage provided.

(2) **Filled Joints**

(a) No waterproofing.
(b) Waterproofing required.

(3) **Keyed Joints**

(a) To hold alinement.
(b) To transfer stress.

(4) **Concealed Joints**

GENERAL

Details that result in entrapment of water or dirt are highly objectionable. Joints should be self-draining and self-cleaning if practicable.

Details that permit minor members to contact before the heavier members do, cause unsightly and annoying defects.

* These classifications apply to both horizontal and vertical expansion joints.

Joints should be provided to prevent weaker members, such as railings, from acting monolithically with major parts.

Materials highly resistant to deterioration should be used.

Joint fillers should be elastic rather than plastic. Their physical texture should provide volume relief locally with a minimum of extrusion.

Sliding joints, those that are shrouded or concealed particularly, should be designed to provide full movement without developing injurious local stresses. Care should be exercised to insure that sliding surfaces shall be parallel and parallel to the direction of movement.

Provision should be made for the free drainage of water to prevent entry into the joint.

When water cannot be prevented from passing through expansion joint it should be collected and disposed of in such manner as to prevent falling on the structure.

COMMENTS ON JOINTS SUBMITTED

Fig. 1.—This joint has given six years' satisfactory service supporting highway traffic, providing expansion for both steel and concrete, but it is recommended detail be revised and the following changes made:

1. Floor beam to be raised to provide cheaper steel fabrication.
2. Provide anchorage for horizontal leg of the top angle. Provide anchorage top angle both sides of joint for horizontal leg. There should be straps extending diagonally downward.
3. Traffic plate should be attached by tap screw for renewal purposes.

Fig. 2.—Represents a joint supporting ordinary highway traffic and has given satisfactory service for four years. Vertical angles should be tied back similar to Fig. 1.

Fig. 3.—Represents joint supporting city street traffic over yard and has given satisfactory service for four years. Details should be revised to provide anchorage. Reverse top left-hand angle to avoid long unsupported leg. Clearance between rivet heads should be provided to meet expansion requirements only.

Fig. 4.—Joints similar to that shown in Fig. 4 have been used for sidewalks of highway bridges, and have given satisfactory service for eight years. Anchorage should angle diagonally downward.

Fig. 5.—Committee does not have service record covering this joint.

Fig. 6 and 7.—These joints have given satisfactory service in highway bridges and will probably become standard practice. Although somewhat expensive, the basic principles of an expansion joint design is taken care of, a clear cut joint being provided and no sliding involved.

Fig. 8.—The reporter on joint shown in Fig. 8 comments as follows:

"The joint shown in Fig. 8 has been in service since 1928. Recent inspection has not been made and no service report covering joint available. However, it is expected this joint will work the same as other joints of this type, that is, the membrane waterproofing laid across the joint will break down within a relatively short period of time, possibly one to two years."

The Committee agrees with the expectation given above.

Fig. 9.—The reporter on joint shown at left of Fig. 9 comments as follows:

"Decks of the type shown in Fig. 9 are usually 4 inches thick and rest on closely spaced I-beams with a maximum of about 10 inches clear between flanges. As far as I know we have never installed such a deck except over a busy street or highway, so that the total length of the structure is never very great. Usually we are able to take care

of expansion at the abutment. We have used the detail shown for the abutment for a great many years, and have never had any trouble. Experience has conclusively shown, therefore, that the detail at the abutment is entirely satisfactory."

The Committee is of the opinion that the detail down the back of the abutment should be revised to provide support against puncture of the membrane after expansion takes place. Slab should be extended and water drip provided.

The expansion joint shown for use between short spans has been in service three years and has proven satisfactory. The Committee is of the opinion that the asphalt plank covering will move out of position and expose the joint.

Joint shown at the right of Fig. 9 represents a joint never built and is subject to the same criticism as the joint shown in the center.

Fig. 10.—The reporter on joint shown in Fig. 10 comments as follows:

"In general it is found that joints in which the weight of the structure is carried on a surface on which sliding is supposed to occur during expansion or contraction of the span practically never function, even when new.

"On structures having an independent bent on each side of joints and some one of numerous details for providing a continuous pavement surface by means of mastic filled spaces, show some merit, at least during the first few seasons of use, provided that great care has been used in keeping the joint absolutely clean before the mastic is introduced. From a practical standpoint this is very difficult, for on every construction job the handling and transporting of materials across the joint present great likelihood that débris of all sorts will find lodgment therein, and in the hurry to start traffic as the structure nears completion the importance of cleanliness at this point is almost sure to be overlooked.

"Assuming that a mastic filled joint has been carefully installed, the first period of hot weather forces much of the softened filler out to the surface of the pavement where it forms a ridge or is carried away by traffic. By the time cold weather causes contraction of the structure the filler has become hard and a gap opens to admit foreign matter of many kinds. After two or three such cycles there is very little of the mastic left in the joint, its place having been taken by incompressible solids. This means that the joint has become inoperative.

"It has been found that where it is not necessary to provide a joint which is waterproof the purpose is best served by some form of clear opening which is self-cleaning and can offer no resistance whatever to the movement of the structure. Whether this opening need be bridged over by interlacing fingers or whether the edges may be straight depends upon the amount of movement for which provision must be made. Details as shown in Fig. 10 have not been in use sufficiently long to furnish service data. General experience has shown that for special details of floor construction, especially at breaks in the floor of movable spans and at expansion joints, steel castings are greatly superior to structural steel assemblies. Although the latter may be lower in first cost, they rust away much more quickly and from constant vibration and impact they become loose and rattle.

"Wherever an expansion joint is provided on a structure carrying street cars it is imperative that the rails be cut at the joint and provision be made to prevent interference with the free movement of the structure."

The Committee has been advised that expansion device shown in Fig. 10 is a scheme for which patent is being applied for.

Fig. 11.—This joint has been in service for twelve years, and is a waterproof expansion joint carrying the direct roadway load. During twelve years' service no complaints have been made as to the effectiveness of the joint.

The joint is subject to heavy electrolytic action, and the under side of the structure forms the roof of a pedestrian tunnel requiring special details.

The Committee is of the opinion waterproofing should be looped over joint to prevent fracture and not laid flat.

This joint offers special details and may be used in some cases.

Fig. 12.—Represents joint for structures carrying railroad tracks and has given satisfactory service for twenty years.

Fig. 13.—This type of joint has been used to some extent and has worked satisfactorily for a number of years, but becomes troublesome and is very expensive to repair. Where possible a simpler joint is favored. In one structure in which this type of joint was used, the waterproofing was protected by a concrete covering for a block paving and considerable difficulty has been experienced due to growing of the concrete protection above the waterproofing. This growth was caused by the mass of concrete not having sufficient tensile strength to return the concrete to the length it occupies during cold weather and absolutely dry. When this action takes place, it ruins the waterproofing and the joint leaks.

Fig. 14.—This joint has been in service for approximately ten years, and has given satisfactory service.

The reporter on joint shown in Fig. 14 includes comments as follows:

"There has been no occasion to repair or refill any of these joints during the period that they have been in use. They apply to structures where there is very little movement of the adjacent units, and it is expected that they will function effectively so long as the expansion joint filler retains its original character, and so long as the waterproofing membrane is not broken.

"The detail shown in Fig. 14 shows more particularly the method adapted to insure an open space between the two adjacent units of concrete. Having this space of proper size throughout, the construction of the joint follows an old established procedure of calking the joint a couple of inches below the top with oakum, filling above the oakum with a satisfactory joint filler, and then carrying the waterproofing membrane and protection across the joint.

"This method of constructing and sealing the joint has been found satisfactory, and no such joints have been exposed for repairs during the ten years that they have been in service."

Fig. 15.—This type of joint has been used for a number of years in railway and highway concrete slab bridges, and has given satisfactory service.

Fig. 16.—Has been used on highways under heavy traffic, and has given satisfactory service. Metal sliding surface should be substituted for the tar paper.

Fig. 17.—This joint used on overhead highway bridge and was found not to give entirely satisfactory service.. During hot weather the filler squeezed out of the joint forming a ridge in the roadway, making a bad riding condition. That part of the filler which was extruded wore away in cool weather, the remaining filler was not sufficient to fill the joint and permitted the entry of water.

This joint requires maintenance.

Fig. 18.—Represents a vertical joint not waterproofed in a wall supporting approaches to a viaduct. Has given two years' satisfactory service.

Fig. 19.—This is a joint used in a station platform, and similar joints have been used satisfactorily five years on highway bridges. The V-shape shown is a double loop in the copper flashing, membrane waterproofing follows the copper and is protected by the asphalt block.

Fig. 20.—This joint used under heavy traffic and has been giving satisfactory service for four years, being developed to eliminate noisy tread plates. Below are comments from report on this joint:

"Has been in service for four years, having been developed to do away with noisy tread plates. Is on main State highway carrying dense heavy traffic. Is giving good service. While the drawing from which this cut was made is of a truss bridge and the beams shown are floor beams, the revision as suggested by the Committee report would make this joint adaptable for I-beam slabs."

Revision referred to above was that bridge seat be raised to bottom of beam and sliding plate provided.

Fig. 21.—Represents a joint supporting highway traffic, and has given satisfactory service. Should be grouped with joints, Figs. 2, 3, 4 and 5.

It is recommended that the report be received as information and the subject reassigned for further study.

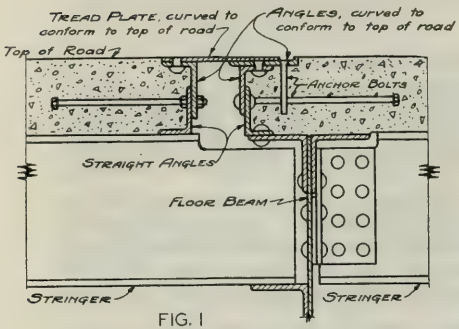


FIG. 1

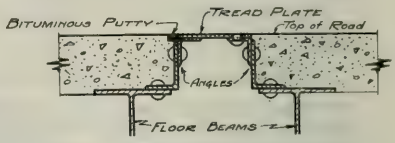


FIG. 2

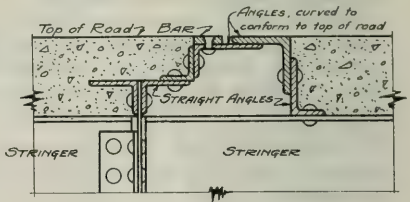


FIG. 3

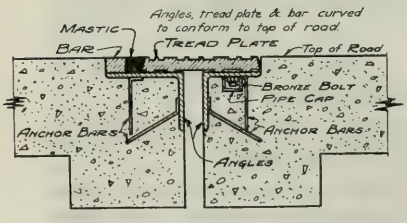


FIG. 5

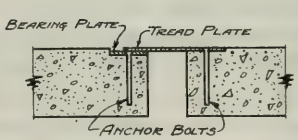


FIG. 4

Fig. 1 to 5.—Expansion Devices of the Sliding Plate Type with Deck not Waterproofed.

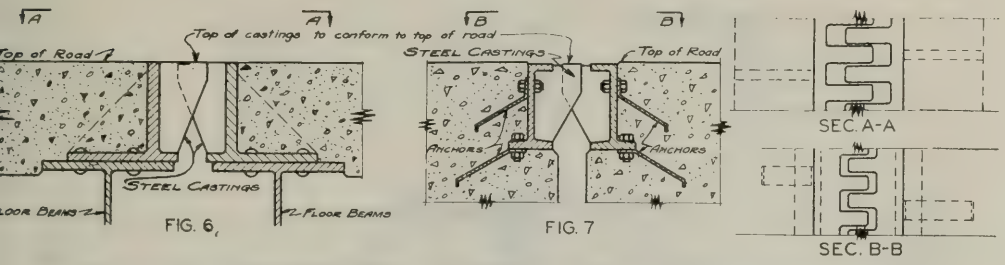


FIG. 6 and 7.—Expansion Devices of Interlaced Castings—Deck not Waterproofed.

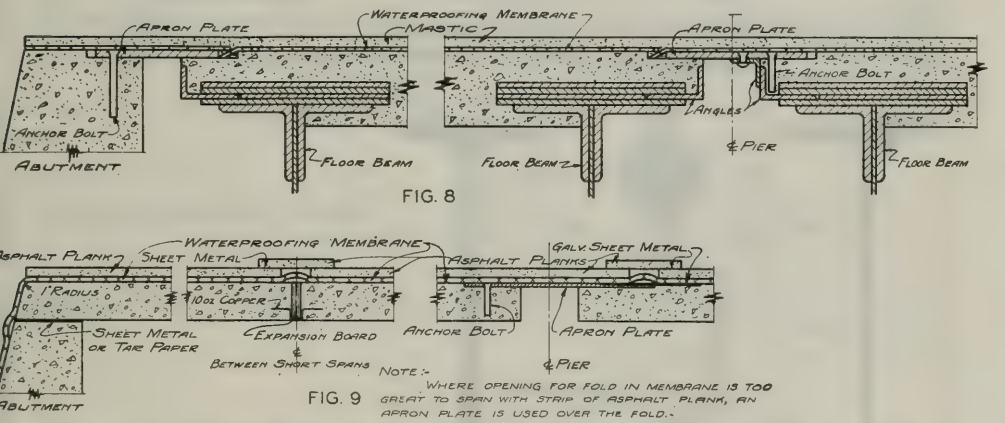


FIG. 8 and 9.—Expansion Devices for Waterproofed Railway Bridge Decks on Steel Spans.

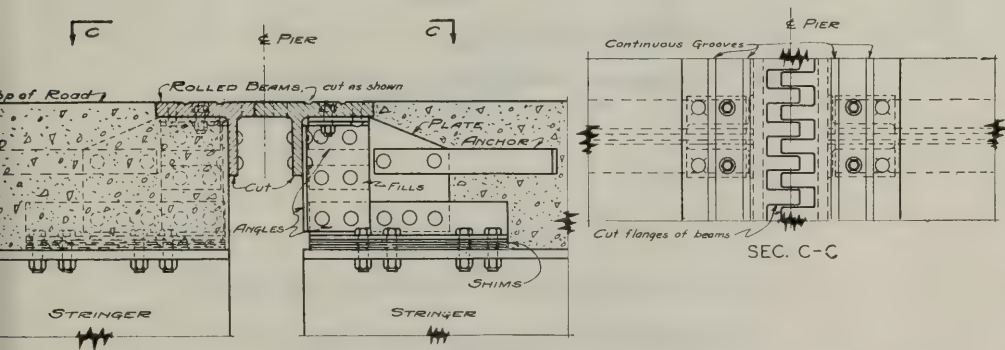


FIG. 10.—Expansion Device of Heavy Wide-Flanged Beams, Flame-Cut and Interlaced Deck not Waterproofed.

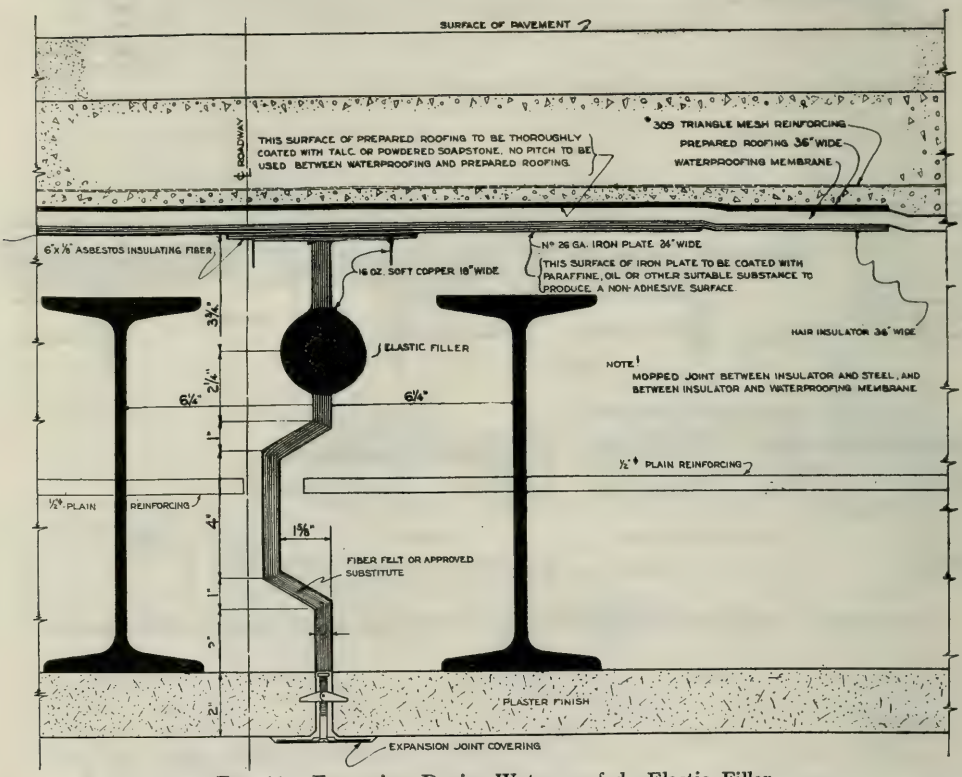


FIG. 11.—Expansion Device Waterproofed—Elastic Filler.

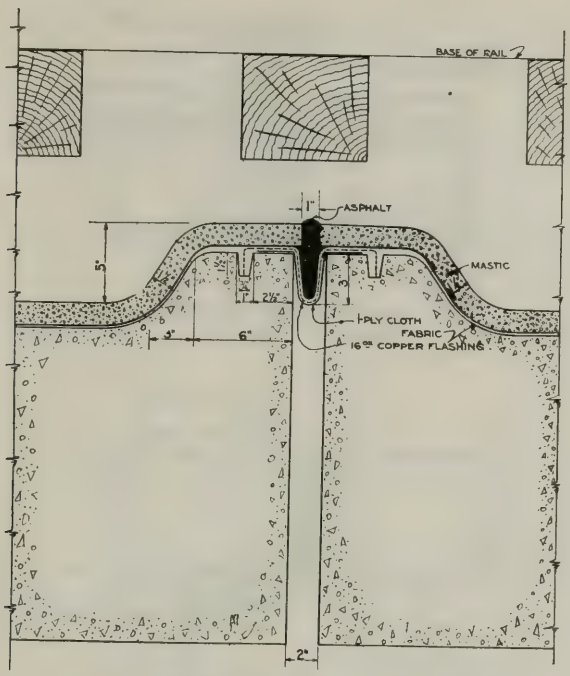


FIG. 12.—Expansion Joint Device—Elastic Filler.

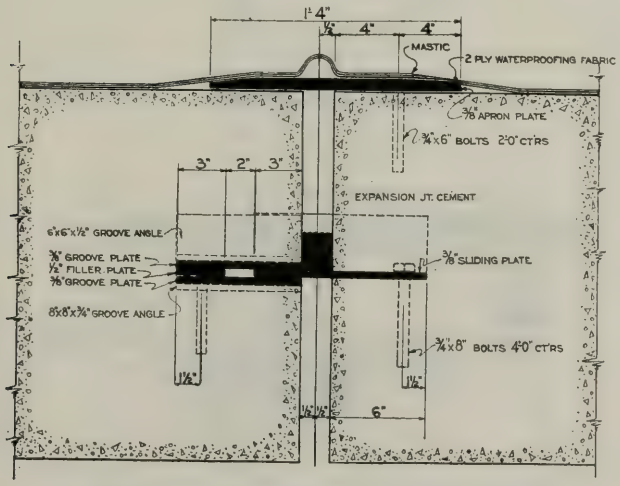


FIG. 13.—Expansion Joint Device Deck Waterproofed—Sliding Plate.

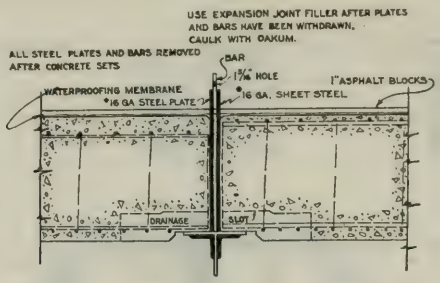


FIG. 14.—Expansion Joint Device—Encased I-Beam Floor.

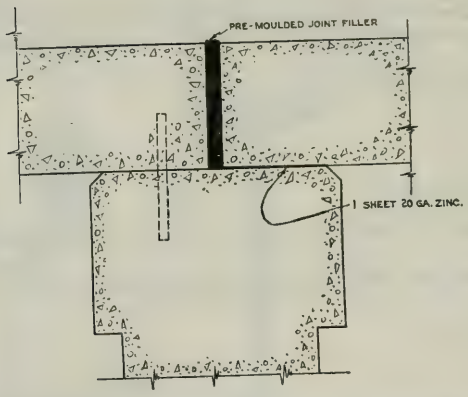


FIG. 15.—Expansion Joint Device—Slab Type Thick Floor.

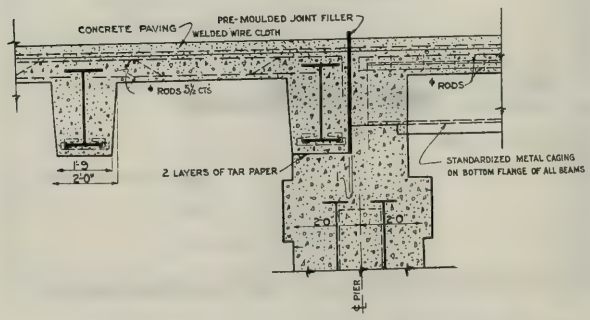


FIG. 16.—Expansion Joint Device—Elastic Filler.

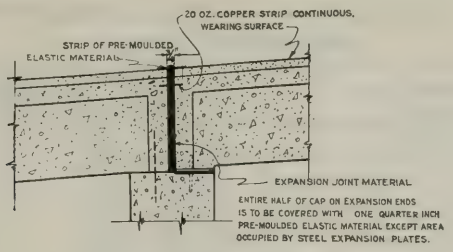


FIG. 17.—Expansion Joint Device—
Elastic Filler.

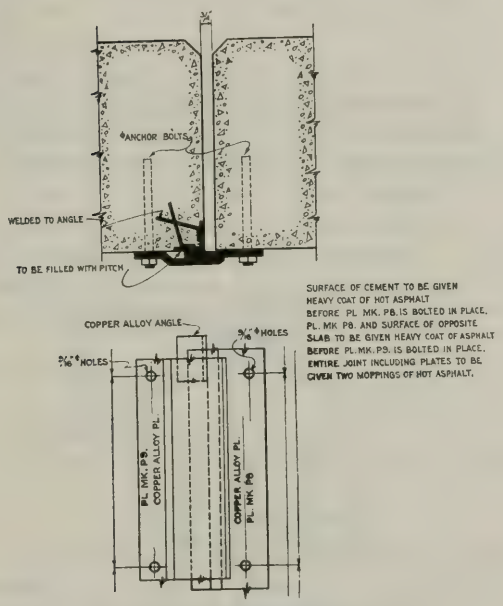


FIG. 18.—Expansion Joint Device—
Slab Type Thick Floor.

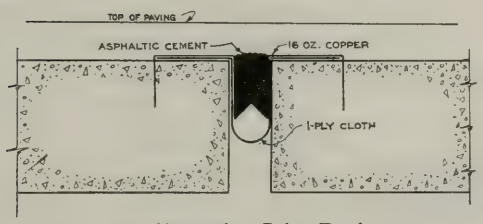


FIG. 19.—Expansion Joint Device—
Slab Type Thick Floor.

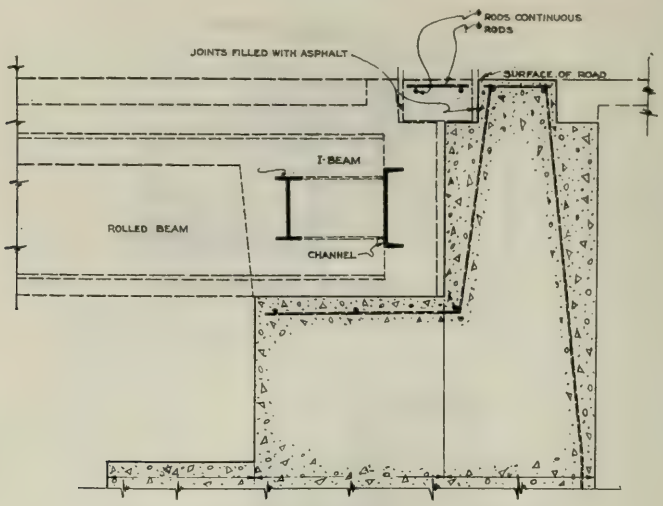


FIG. 20.—Expansion Joint Device at Abutment.

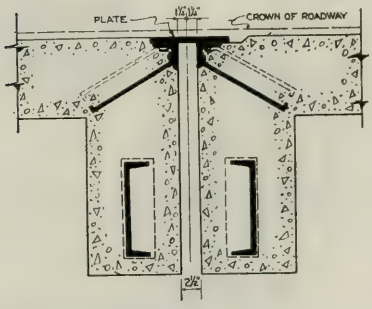


FIG. 21.—Expansion Joint Device—
Not Waterproofed.

REPORT OF COMMITTEE VII—WOODEN BRIDGES AND TRESTLES

H. Austill, *Chairman;*
F. E. Bates,
L. R. Boettcher,
H. M. Buell,
C. R. Chevalier,
H. M. Church,
F. H. Cramer,
W. R. Edwards,
T. H. Gardner,
S. F. Grear,
R. W. Gustafson,
R. P. Hart,
W. E. Hawley,
C. J. Hogue,
W. D. Keeney,
J. A. Newlin,
W. L. Peoples,
G. W. Rear,
D. W. Smith, *Vice-Chairman;*
Arthur Ridgway,
H. T. Rights,
W. R. Roof,
W. J. Ryan,
G. C. Tuthill,
A. T. Upson,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully presents herewith report covering the following subjects:

(1) Revision of Manual.

(2) Simplification of grading rules and classification of timber for railway uses, collaborating with other organizations concerned.

(3) Overhead wooden or combination wooden and steel highway bridges, collaborating with Committees VIII—Masonry and XV—Iron and Steel Structures.

(4) Design of standard wooden trestles for heavy loadings.

(5) Bearing power of wooden piles, with recommendation as to best methods of determination, collaborating with Committee VIII—Masonry.

(6) Best relationships between the energy of hammer and the weight or mass of pile for proper pile driving, to include concrete piles, collaborating with Committee VIII—Masonry.

(7) Improved design of timber structures to give longer life with lower cost of maintenance.

(8) Methods of strengthening existing bridges.

(9) Design of washers, separators, cap-stringer straps and other trestle fastenings.

Action Recommended

1. That proposed changes in the Manual, Appendix A, be adopted.
2. That Appendix B be received as information.
3. That Appendix C be received as information.
4. That Appendix D be received as information.
5. That Appendix E be received as information.
6. That Appendix F be received as information.
7. That Appendix G be received as information.
8. That Appendix H be received as information and the subject be discontinued.
9. That Appendix I be received as information.

Respectfully submitted,

The Committee on Wooden Bridges and Trestles,

H. Austill, *Chairman.*

Bulletin 364, February, 1934.

Appendix A

(1) REVISION OF MANUAL

D. W. Smith, Chairman, Sub-Committee; F. H. Cramer, W. E. Hawley, Arthur Ridgway, G. C. Tuthill.

Your Committee recommends the following changes in the Manual:

As in the 1929 Manual

Page 458—Relative Merits of Open and Ballast Deck Timber Trestles

Par. 2—last line "Vastly less expensive to maintain"

Revision Recommended

Omit.

As in the 1929 Manual

Page 458—heading "Comparative Merits of Ballast Deck and Reinforced Concrete Trestles"

Revision Recommended

"Comparative Merits of Creosoted Timber Ballast Deck and Reinforced Concrete Trestles"

As in the 1929 Manual

Page 458—Par. 5—under heading "Comparative Merits of Ballast Deck and Reinforced Concrete Trestles"

(5) "Notwithstanding the fact that the two materials are, with certain limitations, equally suitable for the construction of trestles, the use of concrete is more in accord with the theory on conservation of natural resources and industrial economy."

Revision Recommended

Omit Par. 5, and renumber Par. 6 and Par. 7.

Page 461

Revision Recommended

Omit the Elevation, Plan and Detail drawing of lag screw.

As in the 1929 Manual

Page 466—Par. 13—"Caps shall be sized and brought to a uniform thickness and even bearing on piles or posts. The side with the most sap shall be placed downward."

Revision Recommended

Omit this paragraph.

As in the 1929 Manual

Page 466—Par. 19—"Stringers shall be sized to a uniform depth at supports. The edges with the most sap shall be placed downward."

Revision Recommended

Omit this paragraph.
Renumber other paragraphs on page 466.

Appendix B

(2) SIMPLIFICATION OF GRADING RULES AND CLASSIFICATION OF TIMBER FOR RAILWAY USES

W. E. Hawley, Chairman, Sub-Committee; H. M. Buell, C. R. Chevalier, H. M. Church, C. J. Hogue, J. A. Newlin, A. T. Upson.

Due to business conditions in which all lumber associational activities have been diverted from improvement of standards to a struggle for existence and to a new emphasis on control of competitive conditions within the lumber producing and selling organization through the opportunities presented under the National Industrial Recovery Act and the N.R.A. Codes, the work of developing standards for lumber and timber has been pushed aside to await a future time when conditions may become normal.

This Association, through this Committee, stands ready to receive all suggestions which may in any manner improve the service of timber in its various forms which are so necessary to the maintenance of the structures which are used by the railways.

The collaboration work with the Mechanical Division, A.R.A. on subject of lumber for freight cars and locomotives has been completed.

Appendix C

(3) OVERHEAD WOODEN OR COMBINATION WOODEN AND STEEL HIGHWAY BRIDGES

R. P. Hart, Chairman, Sub-Committee; F. H. Cramer, G. W. Gustafson, C. J. Hogue, W. D. Keeney, G. W. Rear, G. C. Tuthill.

The Committee invites attention to paragraphs 12, 13, and 14 of specifications for Timber Piles, appearing on page 470 of the 1929 Manual. The dimensions of piles specified are considered by the Committee to be larger than required for piles for use in highway overhead bridges.

The following table of dimensions for "First-Class Piles for Highway Bridges" is therefore presented.

14 (a) Southern pine and Douglas fir piles shall have the following limiting dimensions:

	Diameter 3 Ft. from Butt		*Diameter of Tip*
Length	*Minimum*	*Maximum*	*Minimum*
Under 40 Ft.	12 In.	16 In.	8 In.
40 Ft. to 50 Ft.	13 In.	16 In.	7 In.
50 Ft. to 60 Ft.	14 In.	18 In.	7 In.
Over 60 Feet	14 In.	20 In.	6 In.

14 (b) Oak of all species or cypress piles shall have the following limiting dimensions:

	Diameter 6 Ft. from Butt		*Diameter of Tip*
Length	*Minimum*	*Maximum*	*Minimum*
Under 30 Ft.	12 In.	15 In.	8 In.
30 Ft. to 40 Ft.	12 In.	15 In.	7 In.
Over 40 Feet	12 In.	15 In.	6 In.

14 (c) Western red cedar piles shall have the following limiting dimensions:

	Diameter 6 Ft. from Butt		*Diameter of Tip*
Length	*Minimum*	*Maximum*	*Minimum*
Under 30 Ft.	12 In.	18 In.	8 In.
30 Ft. to 40 Ft.	13 In.	20 In.	8 In.
Over 40 Feet	14 In.	22 In.	7 In.

The Committee also invites attention to an article, "New Type of Composite Beam", by J. F. Seiler, Engineer, Service Bureau, American Wood Preservers' Association, appearing in the November, 1933, issue of Wood Preserving News. This type of construction has been considered by the Committee in further study of its subject and may be included in plans showing recommended practice for highway overhead bridge construction now being prepared.

Appendix D

(4) DESIGN OF STANDARD WOODEN TRESTLES FOR HEAVY LOADING

F. E. Bates, Chairman, Sub-Committee; H. M. Church, W. R. Edwards, S. F. Grear, J. A. Newlin, G. W. Rear, W. R. Roof, W. J. Ryan, D. W. Smith.

Present plans in the Manual provide for a live load of Cooper's E–45 and E–60. A study of modern locomotives indicates loading considerably in excess of these design loads. If full life is to be secured from timber trestles, it is evident that design loading should be increased to not less than E–70. Table 1 below gives the axle loading and Cooper's rating for 14-ft. span for a few typical modern locomotives.

Table 1—Typical Modern Locomotives

		Locomotive		*Cooper's Class 14′ Span*		
Railroad	*Type*	*Average Driving Axle Load*	*Driving Axle Spacing Ft.*	*Moment*	*Bent reaction*	*Tender Average Axle Load*
Western Maryland	2–10–0	77,400	5.62	E–69	E–77	69,300
Northern Pacific	2–8–8–4	70,000	5.62	E–61	E–66	67,000
C.B.&Q.	2–10–4	70,700	5.58	E–63	E–71	64,000
A.T.&S.F.	2–10–4	70,000	6.17	E–59	E–63	63,000
Western Pacific	2–8–8–2	69,100	5.50	E–63	E–63	68,000
Lehigh Valley	4–8–4	67,500	6.42	E–55	E–61	61,000
C.B.&Q.	4–8–4	68,500	6.42	E–53	E–55	58,500
Missouri Pacific	2–8–4	69,000	5.62	E–61.6	E–65	54,000

Attention is called to the axle loading for the locomotive tenders and it will be noted that in many cases they are practically equal to the load on the drivers. Axle spacing in the typical 6-wheel tender trucks is from 50 to 60 inches and for short span lengths such as are used in timber trestle construction the stresses in the stringers are higher under the tender load than under the driver load. Driver loading equal to or exceeding 70,000 lb. per axle is quite common but the increase in axle spacing required for the larger diameter drivers holds Cooper's classification below E–70 for panel lengths 12 to 16 ft.

Table 2 gives a comparison of unit stresses for a selected number and size of stringers for open and ballasted deck. Attention is called to the two methods of computing horizontal shear in the stringers. The Forest Products Laboratory at Madison, Wis., has made an extensive series of tests to determine horizontal shear stresses and their distribution in the beam. Results of these tests were published in the Engineering News–Record dated May 11, 1933. J. A. Newlin, a member of this Committee, has prepared a statement giving results of these tests which appears in Exhibit A. It will be noted that empirical formula used to derive horizontal shear stresses in a beam gives results somewhat in excess of actual stresses as determined by test.

Number and Siz
Reaction on Ber
Dead Load pe
Live Load per
Total Load pe
Kind of Bents_
Number of Piles
Size of Piles or
Area Square Inc
Unit Stress Lb.
Load per Pile o

Bearing Stringer
Area Sq. In.
Area Sq. In.
Unit Bearing Lb
14″ Cap___
16″ Cap___

Stringers—Bend
Dead Load M
Live Load M
Total Load M

Section Modulu
Bending Stress

Longitudinal S
(1st Driver at
Dead Load
Live Load
Total Load
Nominal Area (
Longitudinal Sh

Longitudinal S
Forest Produ
(1st Driver
Dead Load
Live Load
Total Load
Nominal Area (
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Longitudina

TABLE 2.—COMPARISON OF UNIT STRESSES IN PROPOSED TYPE OF TRESTLE BRIDGES DESIGNED FOR COOPER'S E-70 LOADING

	Open Deck									Ballasted Deck							
	12-Foot Panel			13-Foot Panel			14-Foot Panel			13-Ft. Panel				15-Foot Panel			
Number and Size of Stringers	3-10x16	4-8x16	3-9x18	3-9x18	4-10x16	3-10x18	4-10x16	4-9x18	3-10x18	14-7x16	12-8x16	10-10x16	10-9x18	14-8x16	12-10x16	12-9x18	10-10x18
Reaction on Bent																	
Dead Load per Track	10,800	11,200	10,900	11,700	13,500	12,300	14,500	14,600	13,300	34,500	34,300	34,600	34,800	41,300	42,200	41,300	41,300
Live Load per Track	163,600	163,600	163,600	172,000	172,000	172,000	182,700	182,700	182,700	172,000	172,000	172,000	172,000	191,000	191,000	191,000	191,000
Total Load per Track	174,400	174,800	174,500	183,700	185,500	184,300	197,200	197,300	196,000	206,500	206,300	206,600	206,800	232,300	233,200	232,300	232,300
Kind of Bents	Piles Posts	Piles Posts	Piles Posts	Piles Posts	Piles Posts	Piles Posts	Piles Posts	Piles Posts	Piles Posts	Piles Posts	Piles Posts	Piles Posts	Piles Posts	Piles Posts	Piles Posts	Piles Posts	Piles Posts
Number of Piles or Posts	6 6	6 6	6 6	6 6	6 6	6 6	6 6	6 6	6 6	6 6	6 6	6 6	6 6	7 6	7 6	7 6	7 6
Size of Piles or Posts	14"D 12x14	14"D 12x14	14"D 12x14	14"D 12x14	14"D 12x14	14"D 12x14	14"D 12x14	14"D 12x14	14"D 12x14	14"D 12x14	14"D 12x14	14"D 12x14	14"D 12x14	14"D 12x14	14"D 12x14	14"D 12x14	14"D 12x1
Area Square Inches	924 1008	924 1008	924 1008	924 1008	924 1008	924 1008	924 1008	924 1008	924 1008	924 1008	924 1008	924 1008	924 1008	1075 1008	1075 1008	1075 1008	1075 100
Unit Stress Lb. per Sq. In.	188 172	188 172	188 172	200 183	200 183	200 183	212 195	212 195	212 195	225 206	225 206	225 206	225 206	216 231	216 231	216 231	216 23
Load per Pile or Post—Tons	14.5 14.5	14.5 14.5	14.5 14.5	15.4 15.4	15.4 15.4	15.4 15.4	16.3 16.3	16.3 16.3	16.3 16.3	17.3 17.3	17.3 17.3	17.3 17.3	17.3 17.3	16.7 19.5	16.7 19.5	16.7 19.5	16.7 19.
Bearing Stringers to Caps																	
Area Sq. In. (14" wide)	840	896	756	756	1,120	840	1,120	1,008	840	1,176	1,120	1,120	1,008	1,340	1,400	1,260	1,120
Area Sq. In. (16" wide)	960	1,024	864	864	1,280	960	1,280	1,152	960	1,340	1,280	1,280	1,150	1,530	1,600	1,440	1,280
Unit Bearing Lb. per Sq. In.																	
14" Cap	208	193	230	243	165	219	175	196	233	175	184	184	204	174	167	185	208
16" Cap	182	170	202	213	144	192	154	171	204	154	161	161	179	152	146	162	182
Stringers—Bending Stress																	
Dead Load Mom. Ft. Lb. per Rail	9,800	9,800	9,800	10,500	10,500	10,500	13,000	13,000	13,000	26,000	26,000	26,000	26,000	33,000	33,000	33,000	33,000
Live Load Mom. Ft. Lb. per Rail	140,000	140,000	140,000	166,000	166,000	166,000	192,500	192,500	192,500	166,000	166,000	166,000	166,000	219,000	219,000	219,000	219,000
Total Load Mom. Ft. Lb. per Rail	149,800	149,800	149,800	176,500	176,500	176,500	205,500	205,500	205,500	192,000	192,000	192,000	192,000	252,000	252,000	252,000	252,000
Section Modulus (Nominal Size)	1,280	1,365	1,455	1,455	1,710	1,940	1,710	1,940	1,620	1,792	1,720	1,710	1,940	2,048	2,135	2,430	2,160
Bending Stress Lb. per Sq. In.	1,410	1,320	1,240	1,455	1,240	1,100	1,440	1,270	1,520	1,290	1,340	1,350	1,190	1,470	1,420	1,250	1,406
Longitudinal Shear																	
1st Driver at Quarter Pt.																	
Dead Load 1 rail	2,500	2,500	2,500	2,900	2,900	2,900	3,300	3,300	3,300	8,600	8,600	8,600	8,600	10,500	10,500	10,500	10,500
Live Load 1 rail	38,000	38,000	38,000	39,000	39,000	39,000	40,000	40,000	40,000	39,000	39,000	39,000	39,000	44,000	44,000	44,000	44,000
Total Load 1 rail	40,500	40,500	40,500	41,900	41,900	41,900	43,300	43,300	43,300	47,600	47,600	47,600	47,600	54,500	54,500	54,500	54,500
Nominal Area Cross Section Sq. In.	480	512	486	486	640	540	640	648	540	672	640	640	648	768	800	810	720
Longitudinal Shear = 3/2 x Shear, Area	125	118	125	129	93	117	102	100	120	107	112	112	111	107	103	101	114
Longitudinal Shear based on Tests of Forest Products Lab.																	
(1st Driver at 3x Height of Stringer)																	
Dead Load Reaction 1 rail	2,100	2,100	2,100	2,300	2,500	2,300	2,900	2,800	2,600	5,900	5,600	5,500	5,300	7,300	7,200	7,000	6,600
Live Load Reaction 1 rail	32,100	32,100	29,200	32,100	34,800	32,100	37,500	35,000	35,000	35,000	35,000	35,000	32,300	42,000	42,000	38,500	38,500
Total Load Reaction 1 rail	34,200	34,200	31,200	34,300	37,300	34,400	40,400	37,800	37,600	40,900	40,600	40,500	37,600	49,300	49,200	45,500	45,100
Nominal Area Cross Section, Sq. In.	480	512	486	486	640	540	640	648	540	672	640	640	648	768	800	810	720
Longitudinal Shear = 3/2 Reaction Area	107	100	96	106	88	96	95	88	104	91	95	95	87	96	92	84	94

Permissible Working Stresses

	Dense Pine	*Close Grained Fir*
Extreme fiber stress in bending	1400 lb. sq. in.	1400 lb. sq. in.
Compression across grain	250 " " "	240 " " "
Shear across grain	250 " " "	240 " " "
Longitudinal shear	125 " " "	90 " " "

NOTE.—In the design of stringers for ballasted deck trestles it is assumed that the outside or face stringers carry no live load.

NOTE.—Two values are shown for horizontal shear.

Exhibit A

SHEAR IN CHECKED BEAMS

By J. A. Newlin, In Charge Section of Timber Mechanics
Forest Products Laboratory,[1] Forest Service, U. S. Department of Agriculture

This paper is intended to supplement an article on the same subject[2] published in a recent issue of Engineering News–Record by developing an analysis by which the recommended empirical assumptions as to loading may be checked.

In the article referred to it was stated that both from theoretical consideration and from tests the reaction to cause failure by shear could be divided into two parts. The first part, which was there designated as B but is here termed r_1 was shown to be independent of the position of the load. The second term, designated here as r_2, was defined as varying inversely with the distance of the load from the support. The term r_1 represents that part of the total reaction which is associated with shear in the neutral plane and r_2 the part of the total reaction that is carried by the upper and lower parts of the beam acting as two independent beams. It was pointed out that r_1 is the value used in the ordinary shear formula to represent the total reaction.

The above load partition may be expressed algebraically as

$$(1) \quad \frac{r_2}{r_1} = \frac{C}{x^2}$$

where x is the distance of the load from the support. If in this equation x is expressed in absolute units such as inches, then C is dependent upon the height of the beam; but if

$$x = \frac{\text{inches from support}}{\text{height of beam in inches}},$$

as taken, then test data show that C becomes practically a constant for beams of various sizes and degrees of checking from moderate to severe. It is necessary in the further development to assume that equation (1) is true for loads less than those which will cause failure by shear. This assumption appears reasonable, since even at failure the action of the beam is elastic except for a very local area at the bottom of the checks.

The value of C in equation (1) is found from test data to be 2. Substituting this value in equation (1), we have

$$(2) \quad \frac{r_2}{r_1} = \frac{2}{x^2}$$

If P is taken as the concentrated load for which r_1 and r_2 are the two parts of the reaction, then

$$(3) \quad r_1 + r_2 = \frac{P(L-x)}{L}$$

Hence, from (2) and (3)

$$(4) \quad r_1 = \frac{P(L-x)\,x^2}{L(2+x^2)}$$

(Both L and x being in terms of height of beam, it is necessary to know the height of the beam before r_1 can be found.)

The position of P which is most likely to cause shear failure, or, in other words, at which r_1 is a maximum, may be obtained by equating the first derivative of r_1 with respect to x in equation (4) to zero. This yields the equation

$$(5) \quad 4L - 6x - x^3 = 0.$$

With all values of L from 12 to 21, x will be found to be between 3 and 4.

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.
[2] "Wood Beam Design Method Promises Economies," by J. A. Newlin, G. E. Heck, and H. W. March. May 11, 1933.

An equation for uniform load may be developed from equation (4) by replacing P by Wdx, where W is the load per unit of length and dx is the differential of length, and replacing r_1 by dr_1, the differential of reaction associated with shear corresponding to the load Wdx. Thus,

$$(6) \quad dr = \frac{W(L-x)\,x^2}{L(2+x^2)}\,dx$$

Integrating this equation and determining the constant of integration by making $r_1 = 0$ when $x = 0$, we obtain

$$(7) \quad r_1 = \frac{W(L-\frac{x}{2})\,x}{L} - \frac{W}{L}\left[\sqrt{2}\,L\tan^{-1}\frac{x}{\sqrt{2}} - \log_e(2+x^2) + \log_e 2\right]$$

If x is replaced by L in the above equation, we have a uniform load over the entire beam. By this substitution and a slight simplification, the following equation is obtained:

$$(8) \quad r_1 = \frac{WL}{2} - \left[\sqrt{2}\,W\tan\left(\frac{L}{\sqrt{2}}\right) - \frac{W}{L}2.3\log_{10}\left(\frac{2+L^2}{2}\right)\right]$$

In this equation the first term of the right-hand member is the reaction as usually calculated, and the terms in brackets represent the two-beam portion of the reaction. It will be noted that for moderate to long spans the first term in the bracket is almost constant, increasing very slowly with increase in span. The last term is small as compared with the preceding term, and since it contains L^2 in the logarithmic portion and L as a divisor, it will continually decrease as L increases. Within practical limits of span and beam heights this uniform load equation is approximated so closely by

$$(9) \quad r_1 = \frac{9}{10}W\left(\frac{L}{2} - 1\right),$$

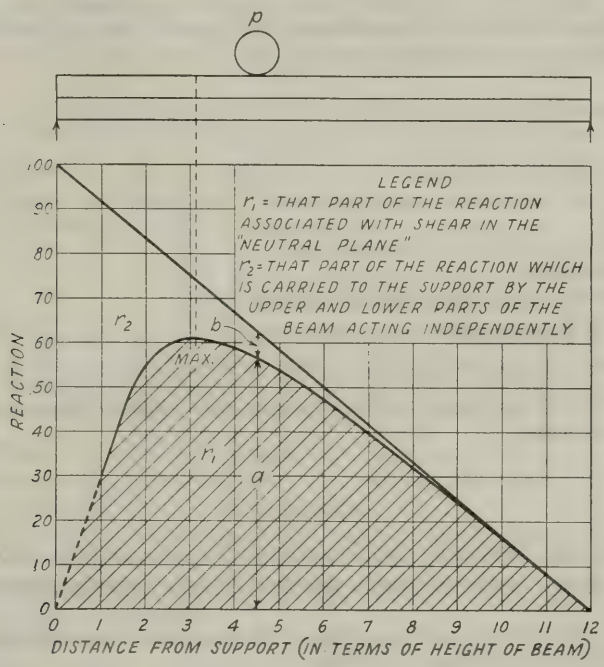
that we could recommend the use of equation (9) to the exclusion of equation (8).

Fig. 1 is a graphical representation of the total, single-beam, and two-beam reaction for a beam with a span-height ratio of 12. For a single concentrated load the ordinates to the straight line represent the total reaction; "a" the ordinate in the cross-hatched portion is the single-beam reaction, associated with shear in the neutral plane. The two-beam reaction is represented by "b", that part of the ordinate in the unshaded area. Placing the load at 3.1 times the height of the beam from the support gives the maximum single-beam reaction and is the point at which to place the load for greatest likelihood of failure by shear. For a uniform load over the entire span, the area under the straight line represents the total reaction, the cross-hatched area, the single-beam reaction, and the unshaded area that portion of the reaction which is carried to the support by two-beam action and is not associated with shear in the neutral plane.

For spans longer than 12, the unshaded area increases only slowly, while the shaded area increases a little more rapidly than the span, and the maximum point of the shaded area moves to the right; but at a span-height ratio of 20 the maximum point is still a little short of four times the height of beam from the support.

The ultimate load at which failure in a checked bridge stringer may be expected can be estimated with fair accuracy from the shearing stress as obtained in standard shear block tests by the use of the above formulas (4) and (9), by estimating the percent-

age of unchecked area to total area at or near the neutral plane between the support and a point located at three times the height of the beam from the support and taking $\frac{4}{9}$ of the stress as obtained by the standard shear test as the expected stress. The $\frac{4}{9}$ is a factor which represents the reduction in average or mean stress at failure due to concentration of stress at the bottom of the checks. This figure is about right for the ordinary seasoned bridge stringer with unequal depths of checking on the two faces.



REACTION DIAGRAM
FOR A
SPAN HEIGHT RATIO OF 12

The use of the above equations in determining the reactions to be used in the ordinary shear formula for rectangular beams and safe stresses as previously published requires the inclusion of a $\frac{10}{9}$ factor in the formulas because of the fact that there was approximately 10 per cent of two-beam reaction in the tests from which the safe stresses were derived.

The following recommendations assume the use of equation (9) for uniform load, and equation (4) whenever a fairly exact shearing strength of a beam is required.

Recommendations

1. Use the ordinary shear formula and the safe stresses previously published.
2. In figuring the reactions,
   (a) neglect all loads within the height of the beam from both supports.
   (b) place the heavy concentrated moving load at three times the height of the beam from the support.
   (c) treat all other loads in the usual manner.

3. If a timber does not qualify under the above recommendations which under certain conditions may be over-conservative, the reactions for the concentrated loads should be checked by the following equation:

$$(10) \quad r^1 = \frac{10P^1(L^1 - x^1)\left(\frac{x^1}{h}\right)^2}{9L^1\left\{2 + \left(\frac{x^1}{h}\right)^2\right\}}$$

in which
r^1 is the reaction to be used as due to a load P^1.
L^1 = span in inches.
x^1 = distance in inches from the reaction to the load P^1.
h = height of beam in inches.

Equation (10) is derived from equation (4) by including a factor of $\frac{10}{9}$ to make it suitable for use with the previously published stresses and a change of L and x from dimensional units to inches.

Appendix E

(5) BEARING POWER OF WOODEN PILES, WITH RECOMMENDATION AS TO BEST METHODS OF DETERMINING

W. R. Edwards, Chairman, Sub-Committee; L. R. Boettcher, H. M. Buell, W. D. Keeney, G. W. Rear, W. J. Ryan, G. C. Tuthill.

The Committee has found it impossible to advance this year the studies previously made.

Appendix F

(6) BEST RELATIONSHIPS BETWEEN THE ENERGY OF HAMMER AND THE WEIGHT OR MASS OF PILE FOR PROPER PILE DRIVING TO INCLUDE CONCRETE PILES

C. R. Chevalier, Chairman, Sub-Committee; T. H. Gardner, R. W. Gustafson, W. D. Keeney, W. L. Peoples, H. T. Rights, W. J. Ryan.

The Committee has found very little data available, as the records of test pile driving do not furnish the weights of piles because generally tests are made to determine the proper length of pile and its actual supporting power at the place where a foundation is to be constructed.

The Committee recommends that actual tests should be made by driving both wood and concrete piles to refusal, at the same location. Using three weights of hammers and proper driving records kept showing weight of piles. Then the piles loaded until equal settlement occurs.

Attention is invited to Bulletin 36 (pages 74 to 85) Public Works of the Navy, reporting the driving and loading of test piles at the Naval Supply Depot, San Diego, Cal.

Appendix G

(7) IMPROVED DESIGN OF TIMBER STRUCTURES TO GIVE LONGER LIFE WITH LOWER COST OF MAINTENANCE

F. H. Cramer, Chairman, Sub-Committee; F. E. Bates, L. R. Boettcher, H. M. Buell, H. M. Church, S. F. Grear, J. A. Newlin, W. L. Peoples, A. T. Upson.

The Committee has made an extensive study of the subject and has accumulated data that it expects to develop into a worthwhile report at a later date, but for the present can only report progress.

Appendix H

(8) METHODS OF STRENGTHENING EXISTING BRIDGES

S. F. Grear, Chairman, Sub-Committee; W. R. Edwards, T. H. Gardner, R. P. Hart, W. L. Peoples, H. T. Rights, W. R. Roof.

In preparing this report, it is assumed that the intent is to outline methods of changing structures to a heavier type and not to cover ordinary repairs. This will cover only wooden trestles.

The strengthening of old structures should be done in a manner to bring them as nearly as possible to the established standard for the district.

Standard materials must be used to the fullest possible extent to avoid the necessity of carrying special sizes for repairs.

In general, treated and untreated materials must not be mixed in the same structure.

Any additional piles or posts placed in a bent should be placed as closely as possible under the rails. This puts the new bearing where it gets the direct load and where it strengthens the existing cap.

When additional stringers are necessary, the old stringers must be loosened and respaced so that the stringers as a unit are symmetrical about the center line of the rail. New stringers must be bolted to the old stringers.

Cross-bracing must be changed so that it will be fastened to the new members of the bent.

Any bolt holes left in treated material must be swabbed with hot creosote oil and filled with treated plugs; any cut surfaces in treated material must be painted with hot creosote oil.

The above methods will, in general, preclude the necessity of putting in heavier caps and ties.

Where strengthening is due to cause other than design, different methods are required.

A frequent source of trouble is the lack of proper bearing power of piles. This condition may be remedied, in some cases, by posts on sills but this is a makeshift and is to be considered only as a temporary arrangement.

Where waterway conditions permit, helper bents will strengthen both the bents and stringers and can generally be so spaced as to become part of a replacement structure.

Trestles which must be raised to have three or more caps should have outside batter piles driven in line with each bent, and the top cap made long enough to reach the tops of these batter piles. These piles serve to stiffen the trestle both laterally and longitudinally. Bracing must be changed so as to be attached to all caps.

Greater stability can be obtained by the use of diagonal bracing placed horizontally from cap to cap just under the stringers.

When additional piles in the line of the bent are required to carry the load, double caps must be used where necessary to distribute the load.

Conclusion

It is the recommendation that this report be received as information and the work of the Sub-Committee be discontinued.

Appendix I

(9) DESIGN OF WASHERS, SEPARATORS, CAP-STRINGER STRAPS, AND OTHER TRESTLE FASTENINGS

R. W. Gustafson, Chairman, Sub-Committee; L. R. Boettcher, T. H. Gardner, R. P. Hart, H. T. Rights, W. R. Roof.

Plans of standard timber trestles and standard trestle fastenings have been received from twenty-three of the larger railroads for the purpose of studying the various designs now used.

We find a number of different methods and details of fastenings being used, although certain details are common on the majority of the roads. The most common details used are as follows:

1. Outer guard-timber is notched and bolted to ties.
2. Ties are boat spiked to stringers.
3. Stringers are drift bolted to caps.
4. Caps are drift bolted to piles.
5. Cast iron separators are used between stringers—type varies.
6. Cast iron O.G. washers are used.
7. Bracing is bolted to piles.

We feel that some of the details are used merely because they have been standard on the system for a long time.

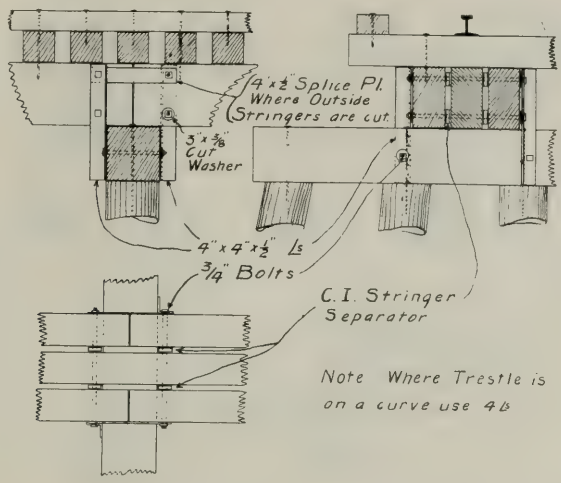
This Sub-Committee will prepare designs of washers, separators, and fastenings with the following points in mind.

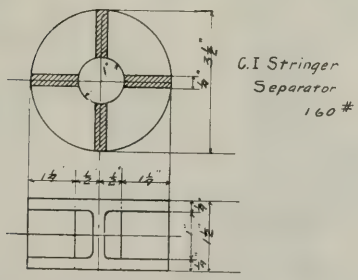
(1) The design of trestle fastenings should be as simple as possible and as few in number as is consistent with good practice and safety.

(2) Washers and separators should be simple in design and efficient but of minimum weight to reduce cost.

(3) Fastenings should be designed so that a minimum amount of moisture can get to the inner fibers of the timber and thus reduce rotting.

Sketch A shows a preliminary design of a separator and a method of fastening stringers to caps without the use of drift bolts. Criticism and suggestions are invited from the Association.



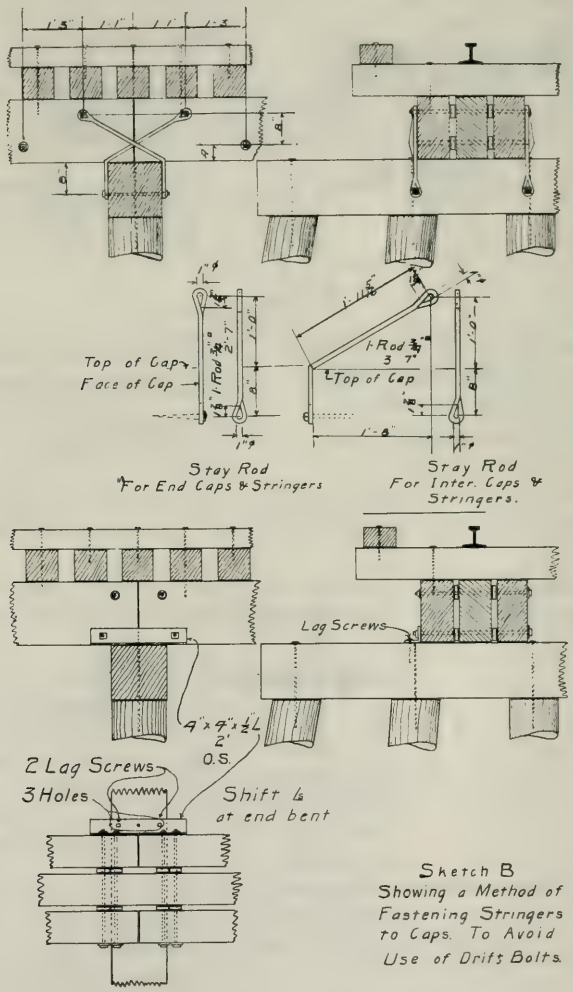


Sketch A

Showing a Method of Fastening Stringers to Caps. To Avoid Use of Drift Bolts

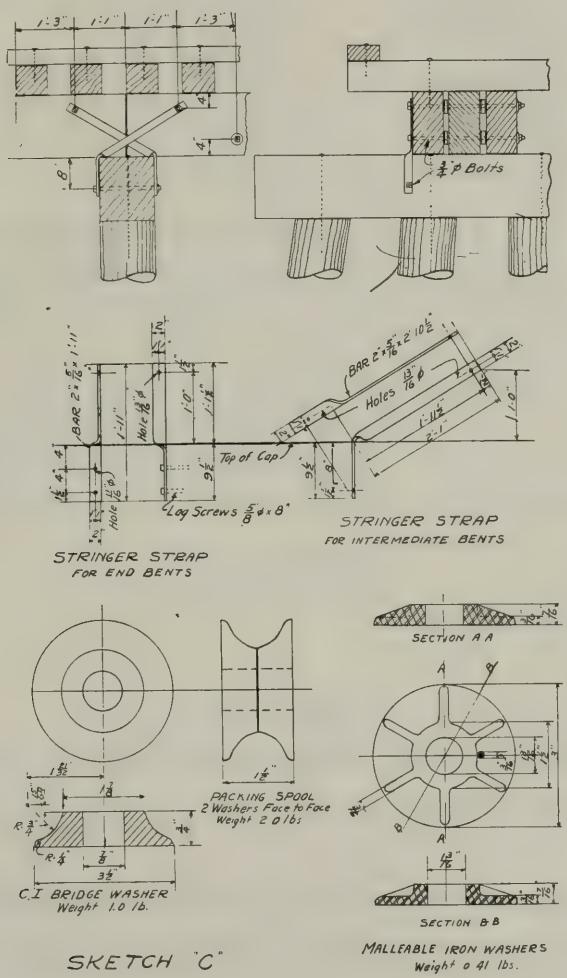
A

Sketch B shows alternate designs which may be used to avoid the use of drift bolts in stringers. The Committee feels that the old custom of using drift bolts in stringers, particularly in untreated timber, is a practice that should be discontinued.



Sketch B
Showing a Method of Fastening Stringers to Caps. To Avoid Use of Drift Bolts.

Sketch C shows preliminary designs of a cast iron washer, a malleable washer, a packing spool using two C.I. washers, and a method of fastening stringers to caps.



SKETCH "C"

REPORT OF COMMITTEE XV—IRON AND STEEL STRUCTURES

A. R. Wilson, *Chairman;*
James Aston,
P. S. Baker,
J. E. Bernhardt,
A. J. Buhler,
A. W. Carpenter,
C. H. Chapin,
Hardy Cross,
O. F. Dalstrom,
R. P. Davis,
F. O. Dufour,
S. Hardesty,
C. S. Heritage,
O. E. Hovey,
F. A. Howard,
J. B. Hunley,
Jonathan Jones,
W. S. Lacher,
P. G. Lang, Jr.
B. R. Leffler,
H. S. Loeffler,
C. H. Mercer,
P. B. Motley,
F. J. Pitcher,
Albert Reichmann,
O. E. Selby,
C. S. Sheldon,
I. L. Simmons,
G. A. Haggander, *Vice-Chairman;*
C. E. Sloan,
S. M. Smith,
H. B. Stuart,
H. C. Tammen,
G. H. Tinker,
G. G. Thomas,
G. H. Trout,
F. E. Turneaure,
F. P. Turner,
R. A. Van Ness,
H. T. Welty,
W. M. Wilson,

Committee.

To the American Railway Engineering Association:

Your Committee respectfully presents herewith report covering the following subjects:

(1) Revision of Manual, including Specifications for Steel Railway Bridges, first edition (Appendix B). It is recommended that these Specifications be received as information.

(3) Tests of steel columns and formulae for design (Appendix A).

(5) Use of alloy steels for structural purposes (Appendix A).

(6) Impact—railway bridges (Appendix A).

(7) Bearing values of small rollers (Appendix A).

On the other subjects in our assignment, namely, Nos. 2, 8, 9, 11, 12, and 13 we report progress.

Respectfully submitted,

The Committee on Iron and Steel Structures,
A. R. Wilson, *Chairman.*

Appendix A

(3) TESTS OF STEEL COLUMNS AND FORMULAE FOR DESIGN

J. B. Hunley, Chairman, Sub-Committee; A. W. Carpenter, Hardy Cross, O. E. Hovey, P. B. Motley, F. E. Turneaure.

(5) USE OF ALLOY STEEL FOR STRUCTURAL PURPOSES

C. H. Mercer, Chairman, Sub-Committee; G. A. Haggander, Adolph J. Buhler, R. P. Davis, S. Hardesty, O. E. Hovey, J. B. Hunley, Jonathan Jones, H. C. Tammen.

(6) IMPACT—RAILWAY BRIDGES

F. E. Turneaure, Chairman, Sub-Committee; J. E. Bernhardt, Adolph J. Buhler, C. H. Chapin, Hardy Cross, O. F. Dalstrom, R. P. Davis, F. O. Dufour, O. E. Hovey, J. B. Hunley, W. S. Lacher, B. R. Leffler, C. H. Mercer, I. L. Simmons, C. E. Sloan, S. M. Smith, W. M. Wilson.

(7) BEARING VALUES OF SMALL ROLLERS

W. M. Wilson, Chairman, Sub-Committee; O. F. Dalstrom, O. E. Hovey, B. R. Leffler. P. B. Motley, O. E. Selby, F. P. Turner, R. A. Van Ness.

The reports of these four sub-committees are included in the Specifications for Steel Railway Bridges, Appendix (B).

Appendix B

(1) REVISION OF MANUAL

SPECIFICATIONS FOR STEEL RAILWAY BRIDGES

For Fixed Spans not Exceeding 400 Feet in Length

First Edition—March, 1934

It is recommended that these Specifications be received as information.

American Railway Engineering Association

SPECIFICATIONS

FOR

STEEL RAILWAY BRIDGES

For Fixed Spans Not Exceeding
400 Feet In Length

1934

(1013

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SPECIFICATIONS FOR STEEL RAILWAY BRIDGES*

For Fixed Spans Not Exceeding 400 Feet in Length

PART I—DESIGN AND MANUFACTURE

SECTION A—PROPOSALS AND DRAWINGS

Definition of Terms

1. The term "Company" means the Railway Company party to the contract. The term "Engineer" means the Chief Engineer of the Company or his subordinates in authority. The term "Inspector" means the inspector representing the Company. The term "Contractor" means the manufacturing or fabricating contractor party to the contract.

Proposals

2. Bidders shall submit proposals conforming to the terms in the letter of invitation. The proposals preferably shall be based on plans and specifications furnished by the Company. Such plans will show the conditions determining the design of the bridge, the general dimensions, stresses, and typical details.

Invitations requiring the Contractor to furnish the design will state the general conditions at the site, such as track spacing, character of foundation, presence of old structures, traffic conditions, etc.

Shop Drawings

3. After the contract has been awarded and before the work is begun, the Contractor shall submit to the Engineer for approval, prints in duplicate of the stress sheets and shop drawings, unless such drawings shall have been prepared by the Company.

Shop drawings shall be made in ink on the dull side of the tracing cloth, 24 by 36 inches in size, including margins. The margin at the left end shall be 1½ inches wide, and the others ½ inch. The title shall be in the lower right-hand corner.

No change shall be made on any approved drawing without the consent, in writing, of the Engineer.

The tracings of the drawings shall be the property of, and be delivered to, the Company after the completion of the contract.

4. The Contractor shall be responsible for the correctness and completeness of his drawings, although the drawings may have been approved by the Engineer.

5. If material is ordered by the Contractor before the drawings have been approved, the Contractor shall assume the risk.

Drawings to Govern

6. If the drawings and the specifications differ, the drawings shall govern.

Patented Devices

7. The Contractor shall protect the Company against claims arising from the use of patented devices or parts proposed by him.

* The Specifications for Movable Railway Bridges of the American Railway Engineering Association, 1922, and current revisions thereof govern those features of movable bridges not covered by these specifications.

Notice to Engineer

8. No material shall be rolled or work done before the Engineer has been notified where the orders have been placed.

SECTION 1—GENERAL FEATURES OF DESIGN

Materials

101. Structures shall be made wholly of structural steel except where otherwise specified. Rivet steel shall be used for rivets only. Forged steel shall be used for large pins, large expansion rollers, and other parts if specified by the Engineer. Cast steel preferably shall be used for shoes, rockers, and bearings. Cast iron may be used only where specifically authorized by the Engineer.

Types of Bridges

102. The types of bridges to be used for various span lengths may be as follows:

Rolled beams for spans up to 40 feet.
Plate girders for spans up to 125 feet.
Riveted trusses for spans 100 feet or longer.
Pin-connected trusses for spans 150 feet or longer.

Spacing of Trusses, Girders, and Stringers

103. The distance between centers of trusses or girders shall be sufficient to prevent overturning by the specified lateral forces. In no case shall it be less than one-twentieth of the span for trusses, nor one-fifteenth of the span for girders.

The girders of deck spans and the stringers of through spans shall be spaced not less than 6 feet 6 inches between centers. If four stringers or girders are used under one track they shall be arranged in pairs, one pair symmetrical about each rail.

Depth Ratios

104. The depth of trusses preferably shall be not less than one-tenth of the span. The depth of plate girders preferably shall be not less than one-twelfth of the span. The depth of rolled beams used as girders and the depth of solid floors preferably shall be not less than one-fifteenth of the span. If smaller depths are used, the sections shall be so increased that the deflection will not be greater than if these limiting depth ratios were not exceeded.

Clearances

105. The clearances on straight track shall not be less than those shown in Fig. 1. On curved track the clearance shall be increased to allow for the overhanging and the tilting of a car 80 feet long, 60 feet between centers of trucks, and 14 feet high.

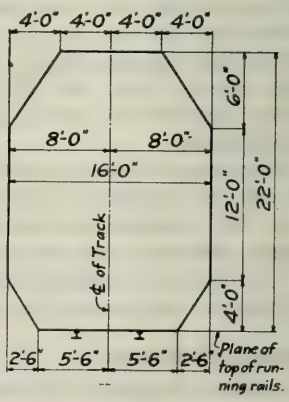

Fig. 1

The superelevation of the outer rail shall be as specified by the Engineer. The distance from the top of rail to the top of tie shall be taken as 8 inches. Where legal requirements provide greater clearances, they shall govern.

Dimensions for Calculation

106. For the calculation of Stresses:

The length shall be:

For trusses and girders, the distance between centers of bearings.

For floor beams, the distance between centers of trusses or girders.

For stringers, the distance between centers of floor-beams.

The depth shall be:

For pin-connected trusses, the distance between centers of pins.

For riveted trusses, the distance between centers of gravity of chords.

Ambiguity of Stress

107. Bridges shall be so designed as to avoid, as far as practicable, ambiguity in the determination of the stresses.

End Floor Beams

108. Spans with floor systems shall have end floor beams unless otherwise specified. End floor beams shall be proportioned for lifting the span without exceeding the design unit stresses more than 50 per cent.

Skew Bridges

109. At the ends of skew bridges, the ends of the supports for each track shall be square with the line of the track.

Floor

110. Ties shall be not less than ten feet long, and spaced not more than six inches apart. They shall be secured against bunching.

SECTION 2—LOADS AND STRESSES

Loads and Forces

201. Bridges shall be proportioned for the following loads and forces:

(a) Dead Load.
(b) Live Load.
(c) Impact.
(d) Centrifugal force.
(e) Other lateral forces.
(f) Longitudinal force.

Stresses from each of these loads and forces shall be shown separately on the stress sheet.

Dead Load

202. In estimating the weight for the purpose of computing dead load stresses, the following unit weights shall be used:

	Pounds per Cubic Foot
Steel	490
Concrete	150
Sand, gravel, and ballast	120
Asphalt-mastic and bituminous macadam	150
Granite	170
Paving bricks	150
Timber	60

The track rails, inside guard rails, and fastenings shall be assumed to weigh 200 pounds per linear foot for each track.

Live Load

203. The recommended live load for each track is the E-72 load shown in Fig. 2 and 3.

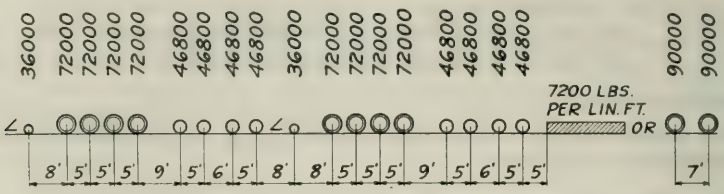

FIG. 2 FIG. 3.

The Engineer shall specify the live load to be used, such load to be proportional to the recommended load, with the same axle spacing.

For bridges on curves, provision shall be made for the increased proportion carried by any truss, girder, or stringer due to the eccentricity of the load.

For members receiving load from more than one track, the proportions of full live load on the tracks shall be as follows:

For two tracks, full live load.

For three tracks, full live load on two tracks and one-fourth on the other track.

For four tracks, full live load on two tracks, one-half on one track, and one-fourth on the remaining one.

The selection of the tracks for these proportions shall be such as will give the greatest live load stress.

Distribution of Live Load

203a. Floor beams that are spaced close enough to carry the track loads without stringers shall be designed for a proportion of the axle load equal to the ratio of the floor beam spacing to the axle spacing. The floor beams shall be connected by solid-web diaphragms at intervals not exceeding 12 times the flange width, with at least one diaphragm for each track.

203b. For ballasted floor bridges, the lateral distribution of the live load shall be taken as uniform over a width of 14 feet but not exceeding the distance between centers of tracks.

Impact

204. To the maximum computed static live load stresses, there shall be added the impact, consisting of:

(a) The rolling or lurching effect:

A percentage of the static live load stress equal to ..... $\frac{100}{S}$

S = spacing, in feet, between centers of longitudinal girders, stringers, or trusses; or length, in feet, of floor beams or transverse girders.

(b) The dynamic effect:

For steam locomotives (hammer blow, track irregularities, and car impact), a percentage of the static live load stress equal to:

Spans less than 100 feet in length ..... $100 - 0.60L$

Spans 100 feet or more in length ..... $\frac{1800}{L-40} + 10$

For electric locomotives (track irregularities and car impact), a percentage of the static live load stress equal to ..... $\frac{360}{L} + 12.5$

L = length, in feet, center to center of bearings, for longitudinal stringers, girders, or trusses;

or, L = length of floor beams or transverse girders, in feet, for floor beams, floor beam hangers, and transverse girders.

The impact shall not exceed 100 per cent. of the static live load.

For members receiving load from more than one track, the impact percentage shall be applied to the static live load on the number of tracks shown below:

Loads received from Two tracks	*Impact applied to*
L = less than 175 feet	Two tracks
L = 175 feet or more	One track
More than two tracks	Any two tracks

Centrifugal Force

205. On curves the centrifugal force (assumed to act 6 feet above the rail) shall be taken equal to a percentage of the live load, including impact, according to the following table.

Degree of Curve	0° 20′	0° 40′	1	2	3	4	5	6	7	8	9	10	11	12
Speed in miles per hour	80	80	80	65	53	46	41	38	35	33	31	29	28	27
Percentage	2½	5	7½	10	10	10	10	10	10	10	10	10	10	10

Wind on Loaded Bridge

206. The wind force shall be considered as a moving load acting in any horizontal direction. The wind force on the bridge shall be taken at 30 pounds a square foot of:

(a) one and one-half times the floor system and girders as seen in elevation.

(b) the vertical projection of all trusses.

but not less than 200 pounds a linear foot of loaded chord and 150 pounds a linear foot of unloaded chord.

The wind force on the train shall be taken as 300 pounds a linear foot on one track, applied 8 feet above the top of the rail.

Wind on Unloaded Bridge

207. If a wind force of 50 pounds a square foot of surface as defined above, on the unloaded bridge, would produce greater stresses than the wind forces specified in Article 206 combined with the live load, the members where such greater stresses occur shall be designed therefor.

Stability of Spans and Towers

208. In calculating the stability of spans and towers, they shall be considered as loaded on one track with empty cars weighing 1200 pounds a linear foot, and subjected

to a wind force of 300 pounds a linear foot applied 8 feet above the top of the rail. On multiple track bridges, this load shall be on the leeward track.

Sway of Engines

209. The lateral force to provide for the effect of the sway of engines, in addition to the wind loads specified, shall be a moving concentrated load of 20,000 pounds applied at the top of rail, in either horizontal direction, at any point of the span.

Transverse Shear between Compression Members

210. The lateral bracing between the compression chords or flanges of trusses and girders and between the posts of viaduct towers shall be proportioned for a transverse shear in any panel equal to 2½ per cent. of the total axial stress in both members in that panel, in addition to the shear from the specified lateral forces.

Longitudinal Force

211. The longitudinal force resulting from the starting and stopping of trains shall be the larger of:

(a) Force due to braking.
Fifteen per cent. of the live load reaction on the tower without impact, but not less than 350 pounds per foot of track.

(b) Force due to traction.
Twenty-five per cent. of the weight on the driving wheels, without impact.

The longitudinal force shall be taken on one track only and shall be assumed to act 6 feet above the top of the rail.

For bridges where, by reason of continuity of members or frictional resistance, much of the longitudinal force will be carried direct to the abutments, such as ballasted deck bridges of only three or four spans, the longitudinal force shall be taken as one-half that specified above.

Reversal of Stress

212. Members subject to reversal of stress shall be designed to resist each kind of stress including impact. The stress for designing the connections shall be that obtained by taking the resultant stress of each kind, tension and compression, including impact, and adding 50 per cent. of the smaller stress to the larger.

Combined Stresses

213. Members subject to both axial and bending stresses (including bending due to floor-beam deflection) shall be so proportioned that the combined fiber stresses will not exceed the allowed axial stress. In members continuous over panel points, only three-fourths of the bending stress computed as for simple beams shall be added to the axial stress.

214. Members subject to stresses produced by a combination of dead load, live load, centrifugal force, and impact, with either lateral or longitudinal forces, or with bending due to lateral or longitudinal forces, may be proportioned for unit stresses 25 per cent. greater than those specified in Article 301; but the section of the member shall be not less than that required for the combination of dead load, live load, centrifugal force, and impact.

Secondary Stresses

215. The design and details shall be such that secondary stresses will be as small as practicable. Secondary stresses due to truss distortion need not be considered in any

member the width of which, measured parallel to the plane of the truss, is less than one-tenth of its length. If the secondary stress exceeds 4,000 pounds per square inch for tension members and 3,000 for compression members, then the excess over 4,000 pounds per square inch for tension members and 3,000 for compression members, shall be treated as a primary stress.

SECTION 3—UNIT STRESSES

Unit Stresses

301. The allowable unit stresses to be used in proportioning the parts of a bridge shall be as follows:

	Pounds Per Square Inch
(a) **Structural and Rivet Steel.**	
Axial tension, structural steel, net section	18,000
Stress in extreme fibers of rolled shapes, girders, and built sections, subject to bending, net section	18,000
Axial compression, gross section, for values of $\frac{l}{r}$ not greater than 140: (See note)	
For riveted ends	$15{,}000-\frac{1}{4}\frac{l^2}{r^2}$
For pin ends	$15{,}000-\frac{1}{3}\frac{l^2}{r^2}$
l = length of member, in inches. r = least radius of gyration of member, in inches.	
Compression in flanges of rolled beams and plate girders, for values of $\frac{l}{b}$ not greater than 40	$18{,}000-5\frac{l^2}{b^2}$
l = length, in inches, of unsupported flange between lateral connections or knee braces. b = flange width, in inches.	
Stress in extreme fibers of pins	27,000
Shear in plate girder webs, gross section	11,000
Shear in power-driven rivets and pins	13,500
Shear in turned bolts and hand-driven rivets	11,000
Bearing on power-driven rivets, pins, outstanding legs of stiffener angles, and other steel parts in contact	27,000

NOTE.—For values of $\frac{l}{r}$ greater than 140 and for columns of known eccentricity, see Appendix A.

Rivets driven by pneumatically or electrically operated hammers are considered power-driven.	
Bearing on rocker pins	9,000
Bearing on turned bolts and hand-driven rivets	20,000
Bearing on expansion rollers and rockers, pounds per linear inch	$600d$
d = diameter of roller or rocker, in inches.	

(b) Cast Steel.

For cast steel shoes and pedestals, the allowable unit stresses for structural steel shall apply.

(c) Masonry.

Bearing pressure:

Granite	1,000
Sandstone and limestone	500
Concrete	750

Effective Diameter of Rivets

302. The nominal diameter of rivets shall be considered the effective diameter.

Effective Bearing Area

303. The effective bearing area of pins, bolts, and rivets shall be the diameter multiplied by the length in bearing; except that for countersunk rivets, half the depth of the countersink shall be deducted.

Slenderness Ratio

304. The slenderness ratio (ratio of length to least radius of gyration) shall not exceed:

100 for main compression members.
120 for wind and sway bracing in compression.
140 for single lacing.
200 for double lacing.
200 for tension members other than eye bars.

SECTION 4—DETAILS OF DESIGN

Thickness of Material

401. Metal, except for fillers, shall be not less than ⅜ inch thick. Parts subject to marked corrosive influences shall be of greater thickness than otherwise or else protected against such influences.

The thickness of gusset plates connecting the chords and web members of a truss shall be proportionate to the stress to be transferred but not less than ½ inch.

Accessibility of Parts

402. Details shall be such that all parts will be accessible for inspection, cleaning, and painting. Closed sections shall be avoided wherever possible.

Drainage of Pockets

402a. Pockets or depressions that would hold water shall have effective drain holes or else be filled with concrete or other suitable material.

Eccentric Connections

403. Eccentric connections shall be avoided if practicable, but if they are unavoidable the members shall be so proportioned that the combined stresses will not exceed the allowable axial stress. Members shall be so arranged that their gravity axes will intersect in a point.

Compression Members

404. Built-up compression members shall be so designed that the main elements of the section will be connected directly to the gusset plates, pins, or other members.

The center of gravity of the section shall coincide as nearly as practicable with the center line of the section. Preferably the segments shall be connected by solid webs.

In members consisting of segments connected by cover plates or lacing, or segments connected by webs, the thickness of the webs of the segments shall be not less than

1/30 of the unsupported distance between the nearest rivet lines or the roots of the flanges of rolled segments. The thickness of the cover plates or webs connecting the segments shall be not less than 1/40 of the unsupported distance between the nearest lines of their connecting rivets or the roots of their rolled flanges.

Outstanding Legs of Angles

405. The width of the outstanding legs of angles in compression, except those reinforced by plates, shall not exceed the following:

(a) For stringer flange angles, ten times the thickness.
(b) For main members carrying axial stress, twelve times the thickness.
(c) For bracing and other secondary members, fourteen times the thickness.

Rigid Members

406. The first and second panels of the bottom chords at each end of single track pin-connected truss spans, and the hip verticals and members with similar functions in all spans shall be rigid.

Strength of Connections

407. Connections shall have a strength not less than that of the member connected, based on the allowable unit stress in the member; except that for longitudinal, transverse, and sway bracing members, the strength of the connections shall be not less than 70 per cent. of the strength of the member nor less than the calculated stress. Connections shall be made as nearly symmetrical as practicable about the axes of the members.

Net Section

408. The width for computing the net section of riveted tension members shall be the least width that can be obtained, for any straight or zig-zag chain of holes, by deducting from the gross width an amount:

$$h + \Sigma w$$

the values of w being given by the formula:

$$w = h - \frac{s^2}{4g}$$

h = diameter of rivet holes, in inches.
s = pitch of any two contiguous holes in the chain, in inches.
g = gage of the same two holes, in inches.
w = width, in inches, to be deducted for that gage.

If the value of w is negative no deduction shall be made for that gage.

The diameter of the hole shall be taken as ⅛ inch greater than the nominal diameter of the rivet.

Effective Sections of Angles

409. If angles in tension are so connected that bending cannot occur in any direction, the effective section shall be the net section of the angle. If connected on one side of a gusset plate, the effective section shall be the net section of the connected leg plus one-half the section of the unconnected leg.

Section at Pin Holes

410. In pin-connected riveted tension members the net section beyond the pin hole, parallel with the axis of the member, shall be not less than the net section of the member. The net section through the pin hole, transverse to the axis of the member, shall be at least 40 per cent. greater than the net section of the member.

Grip of Rivets

411. If the grip of rivets carrying calculated stress exceeds four and one-half times the diameter, the number of rivets shall be increased at least one per cent. for each additional 1/16 inch of grip. If the grip exceeds six times the diameter, the rivets shall be specially designed.

Gage and Pitch of Rivets

412. A gage line is a line, straight or curved, through the centers of a row of rivets. A pitch line is a straight line through the center of a rivet and normal to the gage line.

The gage of rivets is the distance between adjacent parallel gage lines or between the back of an angle and the adjacent gage line. The pitch of rivets is the distance between adjacent pitch lines of rivets on the same or different gage lines.

The maximum pitch in the direction of stress for members composed of plates and shapes shall be seven times the diameter of the rivets.

At the ends of built compression members, the pitch in the direction of stress shall not exceed four times the diameter of the rivets for a distance one and one-half times the width of the member.

Stitch Rivets

412a. Where two or more web plates are in contact, there shall be stitch rivets to make them act in unison. In compression members, the pitch of stitch rivets in the direction of stress shall not exceed 12 times the thickness of the thinnest outside plate connected, and the gage 24 times that thickness. In tension members, the maximum pitch or gage of stitch rivets shall be 24 times that thickness. In tension members composed of two angles in contact, the pitch of the stitch rivets shall not exceed 12 inches.

Minimum Spacing of Rivets

412b. The minimum distance between centers of rivets shall be three times the diameter of the rivets.

Edge Distance of Rivets

413. The distance from the center of a rivet to a sheared edge shall not be less than one and three-fourths times the diameter, nor to a rolled or planed edge less than one and one-half times the diameter, except in flanges of beams and channels, where the minimum distance may be one and one-fourth times the diameter.

The distance from the center of a rivet to the edge of a plate shall not exceed eight times the thickness of the plate.

Sizes of Rivets in Angles

413a. The diameter of the rivets in angles whose size is determined by calculated stress shall not exceed one-fourth of the width of the leg in which they are driven. In angles whose size is not so determined, 1-inch rivets may be used in 3½-inch legs, ⅞-inch rivets in 3-inch legs, and ¾-inch rivets in 2½-inch legs.

Compression Splices

414. Members subject to compression only, if faced for bearing, shall be spliced on four sides sufficiently to hold the abutting parts true to place. The splice shall be as near a panel point as practicable and shall be designed to transmit at least one fourth of the stress through the splice material. Members not faced for bearing shall be fully spliced.

Extra Rivets

415. If splice plates are not in direct contact with the parts which they connect, there shall be rivets on each side of the joint in excess of the number required in the case of direct contact, to the extent of two extra lines for each intervening plate.

If rivets carrying stress pass through fillers, the fillers shall be extended beyond the connected member and the extension secured by enough additional rivets to carry one-half of the stress passing through the fillers.

Stay Plates

416. On the open sides of compression members, the segments shall be connected by lacing bars and there shall be stay plates as near each end as practicable. There shall be stay plates at intermediate points where the lacing is interrupted. In main members the length of the end stay plates shall be not less than one and one-fourth times the distance between the lines of rivets connecting them to the outer flanges. The length of intermediate stay plates shall be not less than three-fourths of that distance and the thickness not less than one-fiftieth of that distance.

417. The segments of tension members composed of shapes shall be stayed together. The length of the stay plates shall be not less than two-thirds of the lengths specified for stay plates on compression members. They shall be connected to each segment by at least three rivets.

Lacing

418. Lacing bars of compression members shall be so spaced that the slenderness ratio of the portion of the flange included between the lacing bar connections will be not more than 40 nor more than two-thirds of the slenderness ratio of the member.

419. In compression members, the shearing stress normal to the member in the plane of the lacing shall be that obtained by the following formula,

$$V = \frac{P}{100}\left(\frac{100}{\frac{l}{r} + 10} + \frac{\frac{l}{r}}{100}\right)$$

V = normal shearing stress.
P = allowable compressive axial load on member.
l = length of member, in inches.
r = radius of gyration of section about the axis perpendicular to plane of lacing, in inches.

To the shear so determined shall be added any shear due to the weight of the member or to other forces, and the lacing proportioned for the combined shear.

420. The shear shall be considered as divided equally among all parallel planes in which there are shear resisting elements, whether continuous plates or lacing. The section of the lacing bars shall be determined by the formula for axial compression in which l is taken as the distance along the bar between its connections to the main segments.

421. If the distance across the member between rivet lines in the flanges is more than 15 inches and a bar with a single rivet in the connection is used, the lacing shall be double and riveted at the intersections. In smaller members single lacing is preferable.

In large members with double lacing, there shall be transverse tie bars between connections to the segments.

The angle between the lacing bars and the axis of the member shall be approximately 45 degrees for double lacing and 60 degrees for single lacing.

422. Lacing bars may be shapes or flat bars. The minimum thickness of flat bars shall be one-fortieth of the distance along the bar between its connections, for single lacing, and one-sixtieth for double lacing, but not less than three-eighths inch.

The diameter of the rivets in lacing bars shall not exceed one-third of the width of the bar. There shall be at least two rivets in each end of lacing bars riveted to flanges more than 5 inches in width.

Reinforcing Plates at Pin Holes

423. Where necessary for the required section or bearing area, the section at pin holes shall be increased on each segment by plates so arranged as to reduce the eccentricity of the segment to a minimum. One plate on each side shall be as wide as the outstanding flanges will allow. At least one full width plate on each segment shall extend to the far edge of the stay plate and the others not less than 6 inches beyond the near edge. These plates shall be connected by enough rivets to transmit the bearing pressure and so arranged as to distribute it uniformly over the full section.

Forked Ends

424. Forked ends will be permitted only where unavoidable. There shall be enough pin plates on forked ends to make the section of each jaw equal to that of the member. The pin plates shall be long enough to develop the pin plate beyond the near edge of the stay plate, but not less than the length required by Article 423.

Floor Beams

425. Floor beams preferably shall be square to the girders or trusses.

End Connection Angles

426. The connection angles for stringers, floor beams, and beams in solid floor sections shall be not less than 4 inches in width and ½ inch in finished thickness.

Proportioning Plate Girders

427. Plate girders and other members subject to bending that produces net tension on one face shall be proportioned by the moment-of-inertia method, using the net section of the compression side as well as of the tension side.

Flange Section

428. The gross section of the compression flange of a plate girder or a rolled beam shall not be less than the gross section of the tension flange.

Flanges of plate girders preferably shall be made without cover plates or side plates unless angles of greater section than 6 inches × 6 inches × ⅞ inch would otherwise be required.

Cover plates shall be equal in thickness, or shall diminish in thickness from the flange angles outward. No plate shall be thicker than the flange angles. When cover plates are used, at least one plate on each flange shall extend the full length of the girder. Other flange plates shall extend far enough to allow two rows of rivets at each end of the plate, beyond the theoretical end, and there shall be enough rivets to develop the plate between its end and the theoretical end of the next plate outside.

In through bridges, there shall be end and corner cover plates.

Flange Rivets

429. The flanges of plate girders shall be connected to the web with enough rivets to transmit to the flange section the horizontal shear at any point together with any load that is applied directly on the flange. Where the ties rest on the flange, one wheel load shall be assumed to be distributed over three feet.

Flange Splices

430. Flange members that are spliced shall be covered by extra material equal in section to the member spliced. There shall be enough rivets on each side of the splice to transmit to the splice material the stress value of the part cut.

Flange angles shall be spliced with angles. No two members shall be spliced at the same cross-section.

Web Splices

431. Splices in the webs of plate girders shall be designed for both the shear and the moment at the splice.

Thickness of Web Plates

431a. The thickness of web plates shall be not less than 1/170 of the clear distance between the flanges.

Stiffeners at Points of Bearing

432. Stiffener angles shall be placed at end bearings and at points of bearing of concentrated loads. The outstanding legs shall be proportioned for bearing and shall extend as nearly as practicable to the edges of the flange angles. Such stiffeners shall not be crimped. They shall be connected to the web by enough rivets to transmit the stress.

Intermediate Stiffeners

433. If the depth of the web between the flanges or side plates of a plate girder exceeds 60 times its thickness, it shall be stiffened by pairs of angles riveted to the web. The spacing of the stiffeners, center to center, shall not exceed 72 inches nor shall the clear spacing be greater than that given by the formula:

$$d = \frac{255000t}{S}\sqrt[3]{\frac{St}{a}}$$

d = clear distance between stiffeners, in inches.
t = thickness of web, in inches.
a = clear depth of web between flanges or side plates, in inches.
S = unit shearing stress, gross section, in web at point considered.

The width of the outstanding leg of each angle shall be not more than 16 times its thickness and not less than two inches plus 1/30 of the depth of the girder.

Bracing of Top Flanges of Through Girders

434. The top flanges of through plate girders shall be braced at the panel points by brackets with web plates. The brackets shall extend to the top flange of the main girder and be as wide as the clearance will allow. They shall be attached securely to a stiffener angle on the girder and to the top flange of the floor beam. On solid floor bridges the brackets shall be not more than twelve feet apart.

Lateral Bracing

435. There shall be bottom lateral bracing in all spans except deck spans less than 50 feet long.

There shall be top lateral bracing in deck spans and in through spans that have enough head room.

Portal and Sway Bracing

436. In through truss spans there shall be portal bracing, with knee braces, as deep as the clearance will allow. There shall be sway bracing at the intermediate panel points

if the trusses are high enough to allow a depth of 6 feet or more for such bracing. If they are not high enough to allow that depth, the top lateral struts shall be of the same depth as the chord, and there shall be knee braces as deep as the clearance will allow.

In deck truss spans there shall be sway bracing at the panel points. The top lateral forces shall be carried to the supports by means of a complete system of bracing in the planes of the top chords and the main end posts.

Rigid Bracing

437. Lateral bracing shall be rigid and there shall be not less than three rivets in each end connection.

If the bracing is a double system and the members meet the requirements for both tension and compression members, both systems may be considered effective simultaneously.

Cross Frames

438. In deck plate girder spans there shall be cross frames at the ends and at intervals not exceeding 18 feet. The end frames shall be proportioned for the centrifugal and lateral forces.

If there are two lines of stringers under each track in panels more than 20 feet in length, they shall be connected by cross frames.

Viaducts

439. Viaducts shall consist of spans supported on bents. The bents preferably shall be composed of not more than two columns braced together. They shall be united in pairs by bracing to form towers except where single bents are necessary.

The columns preferably shall be made with a transverse batter of one horizontal to six vertical for single track viaducts, and one horizontal to eight vertical for double track viaducts.

The bracing of bents and towers shall consist of double systems of rigid diagonals with struts at caps and bases and at intermediate panel points. In double track towers there shall be bracing to transmit the longitudinal force to both sides.

The bottom struts shall be proportioned for either the calculated stresses or a stress in tension or compression equal to one-fourth of the dead load reaction on one pedestal, whichever is greater. The column bearings shall be designed to allow for the expansion and contraction of the tower bracing.

Anchor bolts for viaduct towers and similar structures shall be designed to engage a mass of masonry the weight of which is at least one and one-half times the uplift.

Where long spans are supported on short single bents, the bents shall be made with hinged ends or else the columns and anchorage shall be proportioned for the bending stresses produced by temperature changes and the elastic deformation of the span.

Eye-Bars

440. The thickness of eye-bars shall be not less than one inch nor more than two inches. The section of the head through the center of the pin-hole shall exceed that of the body of the bar by at least 35 per cent. The form of the head shall be submitted to the Engineer for approval before the bars are made. The diameter of the pin shall be not less than eight-tenths of the width of the widest bar attached.

Eye-Bar Packing

441. The eye-bars of a set shall be symmetrical about the central plane of the truss and as nearly parallel as practicable. The inclination of any bar to the plane of the

truss shall not exceed 1/16 inch to the foot. The bars shall be packed close, held against lateral movement, and so arranged that those in the same panel will not be in contact.

Expansion

442. The design shall be such as to allow for the expansion and contraction of the span at the rate of one inch in 100 feet. In spans more than 300 feet long, allowance shall be made for the expansion in the floor.

End Bearings

443. In spans more than 70 feet long, there shall be rollers or rockers at one end. Shorter spans shall be designed to slide on bearings with smooth surfaces.

Bearings and ends of spans shall be secured against lateral movement.

End bearings on masonry preferably shall be raised above the bridge seat by metal pedestals or bolsters.

Rollers

444. Expansion rollers may be either cylindrical or segmental and shall be not less than 6 inches in diameter. They shall be coupled together with substantial side bars and geared to the upper and lower plates. The roller nest shall be so designed that the parts may be cleaned readily.

Pedestals and Shoes

445. Pedestals and shoes preferably shall be made of cast steel. The difference in width between the top and the bottom bearing surfaces shall not exceed twice the vertical distance between them. For hinged bearings, this distance shall be measured from the center of the pin. In built pedestals and shoes, the web-plates and the angles connecting them to the base plate shall be not less than ¾ inch thick. If the size of the pedestal permits, the webs shall be rigidly connected by diaphragms. The minimum thickness of the metal in cast steel pedestals shall be one inch. Pedestals and shoes shall be so designed that the load will be distributed uniformly over the entire bearing surface.

In spans more than 70 feet long there shall be hinged bearings at both ends.

Inclined Bearings

446. For spans on an inclined grade and without hinged bearings, either the sole plates or the masonry plates shall be beveled so that the masonry surfaces may be made level.

Anchor Bolts

447. Anchor bolts shall be not less than 1¼ inches in diameter and long enough to extend 12 inches into the masonry. There shall be washers under the nuts. Anchor bolt holes in pedestals and sole plates shall be ⅜ inch larger in diameter than the bolts and at expansion points the holes in the sole plates shall be slotted.

Camber

448. The camber of trusses shall be equal to the deflection produced by the dead load plus a load of 3000 pounds per foot of track. The camber of plate girders more than 90 feet in length shall be equal to the deflection produced by the dead loal only.

Screw Threads

449. Screw threads shall be U. S. Standard except that for pin ends of diameters greater than 1⅜ inches, the number of threads shall be six to an inch.

Pins

450. In pins more than 9 inches in diameter, there shall be a hole not less than 2 inches in diameter bored longitudinally on the center line.

451. The turned bodies of pins shall be long enough to extend at the ends ¼ inch beyond the outside faces of the parts connected. The pins shall be secured by chambered nuts or by solid nuts and washers. If the pins are bored, through rods with cap washers may be used. The screw ends shall be long enough to allow burring the threads.

452. Pin-connected members shall be secured in such a way as to limit lateral movement on the pin. Filler rings shall be made of metal not less than ½ inch thick.

Name Plates

453. There shall be a name plate, showing in raised letters and figures the name of the manufacturer and the year of construction, bolted to the bridge near each end at a point convenient for inspection.

SECTION 5—WORKMANSHIP

General

501. The workmanship and finish shall be equal to the best general practice in modern bridge shops. Material at the shops shall be kept clean and protected from the weather as far as practicable.

Straightening Material

502. Rolled material must be straight before being laid off or worked. Straightening shall be done by methods that will not injure the material. Sharp kinks and bends shall be cause for rejection.

Finish

503. Shearing, chipping, and flame cutting shall be done neatly and accurately. Portions of the work exposed to view shall be neatly finished.

Punching and Reaming

504. Holes may be punched full-size in material used for lateral, longitudinal, or sway bracing, lacing, stay plates, and diaphragms, if the material is not more than ⅞ inch thick. Holes in main material forming a part composed of not more than three thicknesses may be punched full-size if no thickness is more than ⅝ inch.

If there are more than three thicknesses or if any thickness is more than ⅝ inch, the holes in all of the thicknesses shall be punched-and-reamed, except that if any thickness is more than the nominal diameter of the rivets minus ⅛ inch, the holes in that thickness shall be drilled.

Holes

505. Holes shall be punched full-size, punched-and-reamed, or drilled. The finished hole shall be 1/16 inch larger than the nominal diameter of the rivets.

For holes punched full-size, the diameter of the die shall not exceed that of the punch by more than 3/32 inch.

Holes punched-and-reamed shall be punched 3/16 inch smaller than the nominal diameter of the rivets and reamed to the finished size. Drilled holes shall be drilled to finished size while all of the thicknesses of metal are assembled; or else sub-drilled and reamed as required for punched-and-reamed holes.

Holes shall be cleancut, without torn or ragged edges. Holes that must be enlarged to admit the rivets shall be reamed. Drilling shall be done accurately. Poor matching of holes shall be cause for rejection.

Holes for turned bolts shall be reamed so that the bolt will make a tight fit.

Holes shall be cylindrical and perpendicular to the member.

Reaming and Drilling

506. Reaming and drilling shall be done with twist drills. Drills used for reaming preferably shall be directed by mechanical means.

Reaming after Assembling

507. Reaming shall be done after the pieces forming a built member are assembled and so firmly bolted together that the surfaces are in close contact. Burrs on the outside surfaces shall be removed. The pieces shall be taken apart before riveting, if necessary, and any shavings removed. If it is necessary to take the members apart for shipping or handling, the pieces reamed together shall be so marked that they may be reassembled in the same position. Reamed parts shall not be interchanged.

Shop Assembling

511. The parts of riveted members shall be well pinned and firmly drawn together with bolts before riveting is begun. The drifting done during assembling shall be only such as to bring the parts into position and not to enlarge the holes or distort the metal.

Field Connections

512. Solid floor sections and the floor beams and stringers of open floors shall be assembled in the shop with the girders or trusses, or in suitable frames. The connections shall be made to fit either by reaming the parts while so assembled or by reaming to metal templates.

513. Riveted trusses and the chords of pin-connected trusses shall be assembled to line and fit in the shop, either in whole or in part, and the holes for field connections drilled or reamed while the parts are so assembled; or else such holes shall be reamed to metal templates so placed as to secure the same result as assembling. Holes for other field connections, except those in lateral, longitudinal, and sway bracing, shall be reamed or drilled to a metal template.

Match-Marking

514. Connecting parts assembled in the shop for the purpose of reaming or drilling holes in field connections shall be match-marked, and a diagram showing such marks furnished the Engineer.

Rivets

515. The size of rivets called for on the plans shall be the size before heating.

516. Rivet heads shall be of approved shape and of the same size for each diameter of rivet. They shall be full, neatly made, concentric with the rivet holes, and in full contact with the surface of the member.

Riveting

517. Rivets shall be heated uniformly to a light cherry red and driven while hot. They shall be free from slag, scale, and carbon deposit. When driven, they shall completely fill the holes. Loose, burned, or otherwise defective rivets shall be replaced. In removing rivets, care shall be taken not to injure the adjacent metal and, if necessary, they shall be drilled out. Caulking or recupping shall not be done.

518. Rivets shall be driven by direct-acting riveters where practicable. The pressure shall be continued after the upsetting has been completed.

519. When rivets are driven with a pneumatic riveting hammer, a pneumatic bucker shall be used where practicable.

Field Rivets

520. Field rivets shall be furnished in excess of the nominal number required to the amount of 15 per cent., plus ten rivets, for each size and length.

521. Field rivets shall be free from fins on the under side of the head.

Turned Bolts

522. Turned bolts used to transmit shear shall be 1/32 inch less in diameter than the hole and the threaded portion 1/16 inch less than the shank. The length of the shank shall be 1/16 inch greater than the grip. There shall be a washer not less than ¼ inch thick under the nut.

Planing Sheared Edges

523. Sheared edges of main material more than ⅝ inch thick shall be planed to a depth of ¼ inch. Re-entrant cuts shall be filleted before cutting.

Flame Cutting

523a. Flame cutting of main material shall not be done unless permitted by the Engineer.

Lacing Bars

524. The ends of lacing bars shall be rounded unless otherwise required.

Fit of Stiffeners

525. Stiffeners under the top flanges of deck plate girders and at all bearing points shall be milled or ground to bear against the flange angles. The fit of other stiffeners against the flange angles must be such as to exclude water after being painted. Fillers and splice plates shall be made to fit within ¼ inch at each end.

Web Plates

526. The edges of web plates of girders that have no cover plates shall not be more than ⅛ inch above or below the backs of the top flange angles. Web plates of girders that have cover plates may be ½ inch less in width than the distance back to back of flange angles.

527. In splices of web plates there shall be not more than ⅜ inch opening between the plates.

Facing Floor Beams, Stringers, and Girders

528. Floor beams, stringers, and girders having end connection angles shall be made to exact length. If facing is necessary, the thickness of the end connection angles shall not be reduced more than ⅛ inch at any point.

The ends of the web plate shall be within ⅛ inch of the backs of the end connection angles.

Finished Members

529. Finished members shall be true to line and free from twists, bends, and open joints.

Abutting Joints

530. In joints and splices of compression members and girder flanges, and of tension members where so specified on the drawings, the abutting surfaces shall be faced and

brought to an even bearing. Where the abutting surfaces are not faced, the opening shall not be more than ¼ inch.

Eye-Bars

531. Eye-bars shall be straight, true to size, and free from twists, folds in the neck or head, and other defects. The heads shall be made by upsetting, and rolling or forging. Welding shall not be done. The thickness of the head and neck shall not overrun more than:

1/16 inch for bars 8 inches or less in width.

⅛ inch for bars more than 8 inches and not more than 12 inches wide.

3/16 inch for bars more than 12 inches wide.

532. Both ends of eye-bars shall be bored at the same time. Bars that are to be placed side by side in the structure shall be bored so accurately that the pins may be passed through the holes at both ends at the same time without driving when the bars are placed together.

Annealing

533. Steel that has been partially heated, except that to be used in minor parts, shall be annealed.

Eye-bars shall be annealed by heating uniformly to the proper temperature followed by slow and uniform cooling. Instruments shall be used to determine at all times the temperature of the bars.

A record of the annealing charges showing the bars in each charge and details of the treatment as to the temperature and time, shall be available to the Engineer.

Boring Pin Holes

535. Pin holes shall be bored true to gage, smooth, straight, at right angles with the axis of the member, and parallel with each other, unless otherwise required. The tolerance in the length from outside to outside of pin holes of tension members, or from inside to inside of pin holes of compression members, shall be 1/32 inch for each 75 feet or fraction thereof. In built-up members the boring shall be done after the member has been riveted.

Pin Clearances

537. The difference in diameter between the pin and the pin hole shall be 1/50 inch for pins up to 5 inches in diameter, and 1/32 inch for larger pins.

Pins and Rollers

538. Pins and rollers shall be turned accurately to gage and shall be straight, smooth, and free from flaws.

Screw Threads

539. Screw threads shall be made a close fit in the nut.

Forging Pins

540. Pins more than 7 inches in diameter shall be forged and annealed.

Fitting of Base and Cap Plates

541. The top and bottom surfaces of base and cap plates of columns and pedestals shall be planed, or else hot-straightened, and the parts of members in contact with them faced to fit. Connection angles for base plates and cap plates shall be riveted to compression members before the members are faced.

Surfaces of Bearing Plates and Pedestals

542. Sole plates of plate girders shall be in full contact with the girder flanges. Sole plates and masonry plates shall be planed or straightened. In cast pedestals, bearing surfaces to be in contact with steel or masonry shall be planed.

Pilot Nuts

543. Two pilot nuts and two driving nuts for each size of pin shall be furnished unless otherwise specified.

Shop Painting

544. Unless otherwise specified, steel work shall be given one coat of approved paint after it has been accepted by the Inspector and before it is moved from the shop. Surfaces to be in contact shall be clean when assembled. They shall not be painted. Surfaces not to be in contact but inaccessible shall be painted before the parts are assembled.

Surfaces of metal to be painted shall be cleaned thoroughly, removing rust, mill scale, dirt, oil, grease, and other foreign substances. Oil and grease shall be removed with benzine or gasoline.

Paint shall not be applied on damp or frosted surfaces.

The paint shall be mixed thoroughly and the pigment kept in suspension until the paint is applied.

Machined Surfaces

545. Machine finished surfaces of steel (except abutting joints and base plates) shall be coated with white lead and tallow applied as soon as the surfaces have been finished and accepted by the Inspector.

Facilities for Inspection

546. The Contractor shall afford the Inspector, without charge, facilities for the inspection of materials and workmanship. The Inspector shall be allowed free access to the parts of the works used in the fabrication.

Material Orders and Shipping Statements

547. The Contractor shall furnish to the Engineer as many copies of material orders and shipping statements as the Engineer may require. The weights of the individual members shall be shown on the statements.

Notice of Beginning Work

548. The Contractor shall give the Engineer ample notice of the beginning of rolling in the mill and of work in the shop, in order that inspection may be provided. Material shall not be rolled nor work done in the shop before the Engineer has been so notified.

Inspector's Authority

549. The Inspector shall have authority to reject materials or workmanship that do not meet the requirements of these specifications. In case of dispute, the Contractor may appeal to the Engineer, whose decision shall be final.

Rejection

550. The acceptance by the Inspector of material or finished members shall not be a bar to their rejection later if found defective.

Rejected material and workmanship shall be replaced promptly or made good by the Contractor.

SECTION 6—FULL-SIZE TESTS OF EYE-BARS

Eye-Bars

601. The acceptance of eye-bars shall depend on the results of full-size tests. The Contractor shall furnish, without charge, the testing machines, tools, and labor necessary to make the tests.

Number of Full-Size Tests

602. The number and size of the bars to be tested shall be stipulated by the Engineer before the mill order is placed. The number shall not exceed 5 per cent. of the whole number of bars ordered, with a minimum of two bars.

Selection of Test Bars

603. Test bars shall be of the same section and with pin holes of the same size as the bars ordered and of the same length if within the capacity of the testing machine. They shall be selected by the Inspector from the forged and annealed bars, except that those from bars too long for the testing machine shall be selected from the full-length bars after the heads on one end have been formed. They then shall be cut and the second head formed to make a bar of the greatest length that can be tested.

Physical Properties

604. The minimum requirements for full-size eye-bar tests shall be as follows:

Yield point, in pounds per square inch	33,000
Ultimate strength, in pounds per square inch	60,000
Elongation in 18 feet	12 per cent.

The measurement of the elongation shall be made in the part of the bar that includes the fracture.

The fracture shall be in the body of the bar. The appearance of the surface at the fracture shall be silky throughout, indicating a finely granular structure.

Retests

605. If a bar fails to meet the requirements of Article 604, two additional bars of the same size from the same mill heat shall be tested. The bars represented by the test may be reannealed before the additional bars are tested. If two of the three bars tested fail, the bars of that size and mill heat shall be rejected.

Payment for Test Bars

606. Bars tested full-size shall be paid for by the Company at the same rate as the bars accepted if they meet the requirements of the specifications. Bars that fail to meet the requirements and those rejected as a result of tests, shall not be paid for by the Company. The scrap from bars tested shall be the property of the Contractor.

SECTION 7—WEIGHING AND SHIPPING

Pay Weight

701. The payment in pound-price contracts shall be based on the scale weight of the metal in the fabricated structure, including field rivets shipped, or, if permitted by the Engineer, payment may be based on computed weights. The weight of field paint and cement, boxes and barrels used for packing, and material used for staying or supporting members on cars, shall not be included.

Scale weight in excess of 1½ per cent. above the computed weight shall not be included in the weight paid for.

Variance in Weight

702. If the scale weight of any member is less than 97½ per cent. of the computed weight, it shall be cause for rejection.

Computed Weight

703. The weights of rolled shapes and of plates up to and including 36 inches in width shall be computed on the basis of their nominal weights and dimensions as shown on the approved shop drawings, deducting for copes, cuts, and open holes. For plates more than 36 inches in width, there shall be added to the nominal weight one-half the allowed percentage of overrun in weight given in Article 822.

The weight of the heads of shop driven rivets shall be included in the computed weight.

The weights of castings shall be computed from the dimensions shown on the approved shop drawings, with 10 per cent. added for fillets and overrun.

Weight per Cubic Inch

704. The weight of steel shall be assumed as 0.2833 pound per cubic inch.

The weight of cast iron shall be assumed as 0.2604 pound per cubic inch.

Weighing

705. The finished work shall be weighed in the presence of the Inspector if practicable. The Contractor shall furnish suitable scales and handle the material for weighing.

Marking and Shipping

706. Erection marks shall be painted on the members. The weight shall be marked on members weighing more than 10 tons.

Rivets and bolts shall be in separate packages according to length and diameter. Loose nuts and washers shall be in separate packages according to size. Pins, other small parts, and packages of rivets, bolts, nuts, and washers shall be shipped in boxes, crates, kegs, or barrels, none of which exceeds 300 pounds gross weight. On the outside of each container shall be marked plainly a list and description of the material therein.

Loading Long Girders

707. Long girders shall be so loaded and marked that they may be delivered at the bridge site in position for erection without turning. Instructions for such delivery shall be given to the receiving carrier.

Shipment of Anchorage Material

708. Anchor bolts, washers, and other anchorage or grillage materials to be built into the masonry shall be shipped in time therefor.

PART II—MATERIALS

SECTION 8—STRUCTURAL AND RIVET STEEL

Process

801. Structural and rivet steel shall be made by either or both of the following processes: open-hearth or electric-furnace.

Chemical Composition

802. The steel shall conform to the following requirements as to chemical composition:

	Structural Steel	*Rivet Steel*
Phosphorus, per cent.		
Acid	not over 0.06	not over 0.06
Basic	" " 0.04	" " 0.04
Sulphur, per cent	" " 0.05	" " 0.045
Copper, when copper-bearing steel is specified, per cent	not under 0.20	not under 0.20

Ladle Analyses

803. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus, and sulphur; also copper when copper-bearing steel is specified. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the Engineer, and if it does not conform to the requirements of Article 802, the melt shall be rejected.

Check Analyses

804. Analyses may be made by the Engineer from finished material representing each melt. If the phosphorus and sulphur content thus determined exceeds that specified in Article 802 by more than 25 per cent., the melt shall be rejected.

Rolled Base Plates

804a. Rolled base plates over 2 inches in thickness, for bearing purposes, shall be of steel containing 0.20 to 0.35 per cent. carbon. The chemical composition shall conform to the requirements of Article 802. A discard shall be made from each ingot sufficient to secure sound plates. Physical tests will not be required.

Physical Properties

805. The steel, other than the forms described in Articles 804a and 805a, shall conform to the following requirements as to physical properties, except as specified in Articles 806 and 807:

Properties Considered	*Structural Steel*	*Rivet Steel*
Tensile strength, lb. per sq. in.	60,000–72,000	52,000–62,000
Yield point, minimum, lb. per sq. in.	0.5 tens. str.	0.5 tens. str.
but in no case less than	33,000	28,000
Elongation in 8 in., minimum, per cent	1,500,000 / tens. str.	1,500,000 / tens. str.
Elongation in 2 in., minimum per cent	22	.....

805a. Tension tests will not be required for flat rolled steel 3/16 in. and under in thickness, shapes less than 1 sq. in. in section, and bars, other than flats, less than ½ in. in thickness or diameter.

806. In order to meet the requirements of Article 604 for the physical properties of full-size annealed eye-bars, the manufacturer of the eye-bars shall determine the physical properties required for the specimen tests. The steel shall conform to the requirements of Articles 805, 807, and 810 as to physical properties other than tensile strength.

Modifications in Elongation

807. For structural steel over ¾ in. in thickness or diameter, or under 5/16 in. thick, deductions from the percentage of elongation in 8 in. specified in Article 805 shall be made as follows:

Over ¾ in., deduct 0.25 per cent. for each 1/32 in. over ¾ in., to a minimum elongation of 18 per cent.

Under 5/16 in., deduct 1.25 per cent. for each 1/32 in. under 5/16 in.

Yield Point

808. The yield point shall be determined by the drop of the beam or the halt in the gage of the testing machine.

Speed of Testing Machine

809. The cross-head speed of the testing machine shall be such that the beam can be kept balanced, but in no case shall the values given in the following table be exceeded:

Gage Length of Specimen	*Maximum Cross-head Speed (inches per minute) in determining:*	
	Yield Point	*Tensile Strength*
2 in.	0.5	2.0
8 in.	2.0	6.0

Bend Tests

810. The test specimens for structural steel shall be bent cold through 180 degrees around a pin, the diameter of which is in the following ratio to the thickness of the specimen:

Thickness of Material	*Ratio*
Up to ¾ in., inclusive	½
Over ¾ to 1 in., inclusive	1
Over 1 to 1½ in., inclusive	1½
Over 1½ to 2 in., inclusive	2½
Over 2 in.	3

If there is any cracking on the outside of the bent portion, the melt shall be rejected.

811. The test specimens for rivet bars shall be bent cold through 180 degrees flat. If there is any cracking on the outside of the bent portion, the melt shall be rejected.

Test Specimens

812. Test specimens shall be prepared from the material in its rolled or forged condition except as specified in Article 813.

813. Test specimens for annealed material, except eye-bars, shall be prepared from the material as annealed for use, or from a short length of a full section similarly treated.

Tension and bend test specimens for rivet bars that have been cold drawn shall be normalized before testing.

814. Test specimens shall be so taken that the axis coincides with the direction of rolling and, except as specified in Articles 815 and 816, shall be of the full thickness or diameter of the material as rolled.

Test specimens for plates, shapes, and flats may be machined to the form and dimensions shown in Fig. 4, or with both edges parallel.

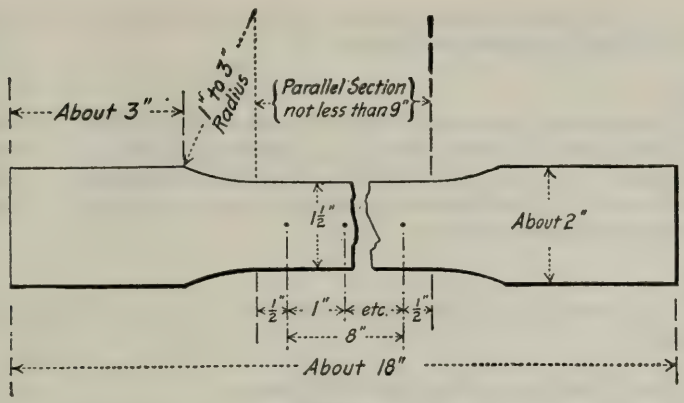

FIG. 4

815. Tension test specimens for material over 1½ inches in thickness or diameter, except pins and rollers, may be machined to a thickness or diameter of not less than ¾ inch for a length of not less than 9 inches, or they may conform to the dimensions shown in Fig. 5.

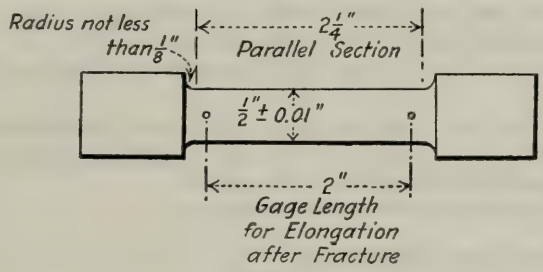

FIG. 5

Bend test specimens for material over 1½ inches in thickness or diameter, except pins and rollers, may be machined to a thickness or diameter of not less than ¾ inch or to a section 1 inch by ½ inch.

816. Tension test specimens for pins and rollers shall conform to the dimensions shown in Fig. 5, and bend test specimens shall be 1 inch by ½ inch in section.

Test specimens for pins and rollers shall be so taken that the axis is one inch from the surface.

817. The machined edges of rectangular bend test specimens may have the corners rounded to a radius of not over 1/16 inch.

Number of Tests

818. Two tension and two bend tests shall be made from each melt, unless the finished material from the melt is less than 30 tons, when one tension and one bend test will be sufficient. If the material rolled from one melt varies ⅜ in. or more in thickness, one tension and one bend test shall be made from both the thickest and the thinnest material regardless of the weight represented.

819. If a test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

Retests

820. A retest shall be allowed if the percentage of elongation of any specimen is less than that specified in Article 805 and if, in addition, any part of the fracture of a 2-inch specimen is more than ¾ inch from the center of the gage length or of an 8-inch specimen is outside the middle third of the gage length as indicated by scribe marks made on the specimen before testing.

Finish

821. The finished material shall be free from injurious defects. The finish shall be workmanlike.

Permissible Variations in Weight and Thickness

822. The section or weight of any structural-size shape or of any universal mill plate up to and including 36 inches in width shall not differ more than 2.5 per cent. from that specified. The thickness and weight of rectangular sheared plates and of rectangular universal mill plates over 36 inches in width shall be governed by the following permissible variations:

(a) When ordered to thickness, the thickness of each plate shall not vary more than 0.01 inch under that ordered. The overweight of each lot of plates in each shipment shall not exceed the amount given in Table II. The term "lot" as applied to Table II means all of the plates of each group width and group thickness.

(b) Plates over 2 in. in thickness shall conform to the permissible variations over the ordered thickness given in Table III. The thickness of each plate shall not vary more than 0.01 in. under that ordered.
Steel is assumed to weigh 0.2833 lb. per cu. in.

Permissible Variations in Diameter

823. The diameter of rivet bars shall not differ from the size ordered more than the amount given in the following table:

Diameter	*Difference in inches*	
	Over	*Under*
Up to and including ½ inch	0.007	0.007
Over ½, up to and including 1 inch	0.010	0.010
Over 1, up to and including 2 inches	1/32	1/64

Identification Marks

824. The name or brand of the manufacturer and the melt number shall be stamped or rolled legibly on the finished material, except that rivet bars, lacing bars, and other small sections shall be made into bundles and the bundles marked for identification. These identification marks shall be stamped legibly on one end of each pin and roller. The melt number shall be marked legibly, by stamping if practicable, on each test specimen.

Inspection

825. The Inspector shall be allowed free access, while work on the contract of the Company is in progress, to the parts of the works used in the manufacture of the mate-

TABLE II.—PERMISSIBLE OVERWEIGHTS OF RECTANGULAR PLATES ORDERED TO THICKNESS

Ordered Thickness Inches	Permissible Excess in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Nominal Weights.									Ordered Thickness, Inches
	Under 48 in.	48 to 60 in., excl.	60 to 72 in., excl.	72 to 84 in., excl.	84 to 96 in., excl.	96 to 108 in., excl.	108 to 120 in., excl.	120 to 132 in., excl.	132 in. or over	
Under 1/8	9	10	12	14						Under 1/8
1/8 to 3/16 excl.	8	9	10	12						1/8 to 3/16 excl.
3/16 to 1/4 excl.	7	8	9	10	12					3/16 to 1/4 excl.
1/4 to 5/16 excl.	6	7	8	9	10	12	14	16	19	1/4 to 5/16 excl.
5/16 to 3/8 excl.	5	6	7	8	9	10	12	14	17	5/16 to 3/8 excl.
3/8 to 7/16 excl.	4.5	5	6	7	8	9	10	12	15	3/8 to 7/16 excl.
7/16 to 1/2 excl.	4	4.5	5	6	7	8	9	10	13	7/16 to 1/2 excl.
1/2 to 5/8 excl.	3.5	4	4.5	5	6	7	8	9	11	1/2 to 5/8 excl.
5/8 to 3/4 excl.	3	3.5	4	4.5	5	6	7	8	9	5/8 to 3/4 excl.
3/4 to 1 excl.	2.5	3	3.5	4	4.5	5	6	7	8	3/4 to 1 excl.
1 to 2 incl.	2.5	2.5	3	3.5	4	4.5	5	6	7	1 to 2 incl.

NOTE.—The weight of individual plates ordered to thickness shall not exceed the nominal weight by more than one and one-third the amount given in this table.

TABLE III.—PERMISSIBLE VARIATIONS OVER ORDERED THICKNESS OF PLATES OVER 2 IN. IN THICKNESS

Ordered Thickness, inches	Permissible Excess in Thickness, inches					
	Width, inches					
	Up to 36, excl.	36 to 60, excl.	60 to 84, excl.	84 to 120, excl.	120 to 132, excl.	132 to 144, excl.
Over 2 to 3 excl.	0.062(1/16)	0.094(3/32)	0.109(7/64)	0.125(1/8)	0.125(1/8)	0.141(9/64)
3 to 4 excl.	0.078(5/64)	0.094(3/32)	0.109(7/64)	0.125(1/8)	0.125(1/8)	0.141(9/64)
4 to 6 excl.	0.094(3/32)	0.125(1/8)	0.141(9/64)	0.141(9/64)	0.156(5/32)	0.172(11/64)
6 to 8 excl.	0.109(7/64)	0.125(1/8)	0.156(5/32)	0.156(5/32)	0.172(11/64)	
8 to 10 excl.		0.172(11/64)	0.187(3/16)	0.187(3/16)		
10 to 12 excl.		0.187(3/16)	0.234(15/64)	0.234(15/64)		
12 to 15 excl.		0.219(7/32)	0.250(1/4)			

Tables II and III are identical with the tables of the same numbers in A. S. T. M. Standards, Serial Designation A 7-33.

rial ordered. The manufacturer shall, without charge, afford the Inspector facilities for making the inspection and furnish the test specimens required, and the testing machines, tools, and labor necessary to make the tests.

Inspections and tests (except check analyses) shall be made at the place of manufacture before shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

826. Unless otherwise agreed, any rejection based on check analyses shall be reported within five working days from the receipt of the samples.

Specimens representing material rejected as the result of check analyses, shall be preserved for two weeks from the date of the report. In case of dissatisfaction with the result, the manufacturer shall be allowed a rehearing within that time.

Material in which any injurious defect is found after its acceptance at the works will be rejected and the manufacturer so notified.

SECTION 9—STRUCTURAL SILICON STEEL

Process

901. Structural silicon steel shall be made by either or both of the following processes: open-hearth or electric-furnace.

Discard

902. A discard shall be made from each ingot sufficient to secure freedom from injurious piping and undue segregation.

Chemical Composition

903. The steel shall conform to the following requirements as to chemical composition:

	Ladle Analyses	*Check Analyses*
Carbon, per cent	Not over 0.40	Not over 0.44
Phosphorus, per cent.		
Acid	" " 0.06	" " 0.075
Basic	" " 0.04	" " 0.05
Sulphur, per cent	" " 0.05	" " 0.063
Silicon, per cent	Not under 0.20	Not under 0.18

Ladle Analyses

904. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus, sulphur, and silicon. The analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the Engineer, and if the percentages of carbon, phosphorus, sulphur and silicon do not conform to the requirements of Article 903 for ladle analyses, the melt shall be rejected.

Check Analyses

905. Analyses may be made by the Engineer from finished material representing each melt. If the chemical composition thus determined does not conform to the requirements of Article 903 for check analyses, the melt shall be rejected.

Physical Properties

906. The steel shall conform to the following requirements as to physical properties, except as specified in Article 907:

Tensile strength, lb. per sq. in.	80,000 to 95,000
Yield point, min., lb. per sq. in.	45,000
Elongation in 8 in., min., per cent	$\frac{1{,}500{,}000}{\text{tens. str.}}$
Elongation in 2 in., min., per cent	$\frac{1{,}600{,}000}{\text{tens. str.}}$
Reduction of area, min., per cent	30

Modification in Ductility

907. For structural silicon steel over ¾ inch thick, deductions from the percentages of elongation and reduction of area specified in Article 906, shall be made as follows:

A deduction of 0.25 per cent, from the elongation in 8 inches for each 1/16 inch above ¾ inch, to a minimum elongation of 14 per cent.

A deduction of 0.50 per cent. from the reduction of area for each 1/16 inch above ¾ inch, to a minimum reduction of area of 24 per cent.

Yield Point

908. The yield point shall be determined by the drop of the beam or the halt in the gage of the testing machine when operated at a cross-head speed not exceeding ½ in. per minute. The testing machine shall not be stopped to obtain the drop of the beam or the halt in the gage.

Bend Tests

909. Test specimens shall be bent cold through 180 degrees around a pin, the diameter of which is in the following ratio to the thickness of the specimen:

Thickness of Material	*Ratio*
Up to ¾ in. inclusive	1
Over ¾ to 1 in. wide	1½
Over 1 to 1¼ in. wide	2
Over 1¼	2½

If there is any cracking on the outside of the bent portion, the melt shall be rejected.

Drift Tests

909a. Punched rivet holes with their centers two diameters from a planed edge shall be enlarged by drifting until the diameter is increased 50 per cent. If there is any cracking of the metal the melt shall be rejected.

Test Specimens

910. Test specimens shall be prepared from the material in its rolled or forged condition except as specified in Article 911.

911. Test specimens for annealed material shall be prepared from the material as annealed for use, or from a short length oi a full section similarly treated.

912. Test specimens shall be so taken that the axis coincides with the direction of rolling and, except as specified in Article 913, shall be of the full thickness or diameter of the material as rolled.

Test specimens for plates, shapes, and flats may be machined to the form and dimensions shown in Fig. 4, Article 814, or with both edges parallel.

913. Tension test specimens for material over 1½ in. in thickness or diameter may be machined to a thickness or diameter of not less than ¾ inch for a length of not less than 9 inches.

Bend test specimens for material over 1¼ inches in thickness or diameter may be machined to a thickness or diameter of not less than ¾ inch or to a section 1 inch by ½ inch.

914. The machined edges of rectangular bend test specimens may have the corners rounded to a radius of not over 1/16 inch.

Number of Tests

915. Two tension tests and one bend test shall be made from each melt, except that if the material rolled from one melt varies ⅜ inch or more in thickness, one tension and one bend test shall be made from both the thickest and the thinnest material.

916. If a test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

Retests

917. A retest shall be allowed if the percentage of elongation of any specimen is less than that specified in Article 906, and if, in addition, any part of the fracture is outside the middle third of the gage length as indicated by scribe marks made on the specimen before testing.

Permissible Variations in Weight and Thickness

918. The section or weight of each piece of steel shall not differ more than 2.5 per cent. from that specified except in the case of sheared plates, which shall be governed by the requirements of Article 822 for rectangular sheared plates.

Finish

919. The finished material shall be free from injurious defects. The finish shall be workmanlike.

Identification Marks

920. The name or brand of the manufacturer and the melt number shall be stamped or rolled legibly on the finished material. The melt number shall be marked legibly, by stamping if practicable, on each test specimen.

Inspection

921. The Inspector shall be allowed free access, while work on the contract of the Company is in progress, to the parts of the works used in the manufacture of the material ordered. The manufacturer shall, without charge, afford the Inspector facilities for making the inspection and furnish the test specimens required, and the testing machines, tools, and labor necessary to make the tests.

Inspections and tests (except check analyses) shall be made at the place of manufacture before shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

922. Unless otherwise agreed, any rejection based on check analyses shall be reported within five working days from the receipt of the samples.

Specimens representing material rejected as the result of check analyses, shall be preserved for two weeks from the date of the report. In case of dissatisfaction with the result, the manufacturer shall be allowed a rehearing within that time.

Material in which any injurious defect is found after its acceptance at the works will be rejected and the manufacturer so notified.

SECTION 10—STRUCTURAL NICKEL STEEL

Process

1001. Structural nickel steel shall be made by either or both of the following processes: open-hearth or electric-furnace.

Discard

1002. A discard shall be made from each ingot intended for eye-bars sufficient to secure freedom from injurious piping and undue segregation.

Chemical Composition

1003. The steel shall conform to the following requirements as to chemical composition:

Carbon, per cent	Not over 0.45
Manganese, per cent	" " 0.70
Phosphorus, per cent.	
Acid	" " 0.05
Basic	" " 0.04
Sulphur, per cent	" " 0.05
Nickel, per cent	Not under 3.25

Ladle Analyses

1004. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus, sulphur, and nickel. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the Engineer, and if it does not conform to the requirements of Article 1003, the melt shall be rejected.

Check Analyses

1005. Analyses may be made by the Engineer from finished material representing each melt. If the chemical composition thus determined does not conform to the requirements of Article 1003, the melt shall be rejected.

Physical Properties

1006. The steel shall conform to the following requirements as to physical properties, except as specified in Articles 1007 and 1008:

Properties Considered	*Plates, Shapes and Bars*	*Eye-bar Flats and Rollers, Unannealed*	*Eye-bar Flats and Pins, Annealed*
Tensile strength, lb. per sq. in.	85,000–100,000	95,000–110,000	90,000–105,000
Yield point, min., lb. per sq. in.	50,000	55,000	52,000
Elongation in 8 in., min., per cent	$\frac{1,500,000}{\text{tens. str.}}$	$\frac{1,500,000}{\text{tens. str.}}$	20
Elongation in 2 in., min., per cent	18	16	20
Reduction of area, min., per cent	25	25	35

Tests of annealed specimens of eye-bar flats shall be made for information only.
The elongation of pins and rollers shall be measured in 2 inches.

Test of Eye-Bars

1007. Full-size tests of annealed eye-bars shall conform to the following requirements as to physical properties:

Tensile strength, lb. per sq. in.	85,000 to 100,000
Yield point, min., lb. per sq in.	48,000
Elongation in 18 ft., min., per cent	10
Reduction of area, min., per cent	30

Modification in Elongation

1008. For plates, shapes, and unnealed bars over 1 in. in thickness, a deduction of 0.25 per cent. from the percentage of elongation in 8 in. specified in Article 1006, shall be made for each 1/32 in. in thickness above 1 in. to a minimum elongation of 14 per cent.

Yield Point

1009. The yield point for test specimens shall be determined by the drop of the beam or the halt in the gage of the testing machine; for full-size eye-bars by the halt in the gage.

Speed of Testing Machine

1010. The cross-head speed of the testing machine, for specimen tests, shall be such that the beam of the machine can be kept balanced, but in no case shall the values given in the following table be exceeded:

Gage Length of Specimen	*Maximum Cross-head Speed (inches per minute) in determining:*	
	Yield Point	*Tensile Strength*
2 in.	0.5	2.0
8 in.	2.0	6.0

Character of Fracture

1011. The appearance at the surface of the fracture of broken tension test specimens shall be either silky or finely granular, of uniform color, and free from coarse crystals.

Bend Tests

1012. Test specimens shall be bent cold through 180 degrees as follows:

(a) For material ¾ inch or less in thickness, around a pin the diameter of which is equal to the thickness of the specimen.

(b) For material more than ¾ inch in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

If there is any cracking on the outside of the bent portion, the melt shall be rejected.

Drift Tests

1013. Punched rivet holes with their centers two diameters from a planed edge shall be enlarged by drifting until the diameter is increased 50 per cent. If there is any cracking of the metal the melt shall be rejected.

Test Specimens

1014. Specimens shall be prepared for testing from the material in its rolled or forged condition except as specified in Article 1015.

1015. Test specimens for annealed material, except eye-bars, shall be prepared from the material as annealed for use, or from a short length of a full section similarly treated.

1016. Test specimens shall be so taken that the longitudinal axis coincides with the direction of rolling and, except as specified in Articles 1017 and 1018, shall be of the full thickness or diameter of the material as rolled.

Test specimens for plates, shapes, and flats may be machined to the form and dimensions shown in Fig. 4, Article 814, or with both edges parallel.

1017. Tension test specimens for material over 1½ inches in thickness or diameter, except pins and rollers, may be machined to a thickness or diameter of not less than ¾ inch for a length of not less than 9 inches, or they may conform to the dimensions shown in Fig. 5, Article 815.

Bend test specimens for material over 1½ inches in thickness or diameter, except eye-bar flats, pins, and rollers, may be machined to a thickness or diameter of not less than ¾ inch or to a section 1 inch by ½ inch.

1018. Tension test specimens for pins and rollers shall conform to the dimensions shown in Fig. 5, Article 815, and bend test specimens shall be 1 inch by ½ inch in section.

Test specimens for pins and rollers shall be so taken that the axis is one inch from the surface.

1019. The machined edges of rectangular bend test specimens may have the corners rounded to a radius of not over 1/16 inch.

Number of Tests

1020. One tension and one bend test shall be made from each melt, except that if the material rolled from one melt varies ⅜ inch or more in thickness, both the thickest and the thinnest material shall be so tested.

1021. If a test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

Retests

1022. A retest shall be allowed if the percentage of elongation of any specimen is less than that specified in Article 1006 and if, in addition, any part of the fracture of a 2-inch specimen is more than ¾ inch from the center of the gage length or, of an 8-inch specimen is outside the middle third of the gage length as indicated by scribe marks made on the specimen before testing.

Finish

1023. The finished material shall be free from injurious defects. The finish shall be workmanlike.

Permissible Variations in Weight and Thickness

1024. The permissible variation in weight of structural nickel steel plates shall be the same as provided in Article 822 for structural steel plates.

Identification Marks

1025. The name or brand of the manufacturer and the melt number shall be stamped or rolled legibly on the finished material, except that rivet bars, lacing bars, and other small sections shall be made into bundles and the bundles marked for identification. These identification marks shall be stamped legibly on one end of each pin and roller. The melt number shall be marked legibly, by stamping if practicable, on each test specimen.

Inspection

1026. The Inspector shall be allowed free access, while work on the contract of the Company is in progress, to the parts of the works used in the manufacture of the mate-

rial ordered. The manufacturer shall, without charge, afford the Inspector facilities for making the inspection and furnish the test specimens required, and the testing machines, tools, and labor necessary to make the tests.

Inspections and tests (except check analyses) shall be made at the place of manufacture before shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

1027. Unless otherwise agreed, any rejection based on check analyses shall be reported within five working days from the receipt of the samples.

Specimens representing material rejected as the result of check analyses, shall be preserved for two weeks from the date of the report. In case of dissatisfaction with the result, the manufacturer shall be allowed a rehearing within that time.

Material in which any injurious defect is found after its acceptance at the works will be rejected and the manufacturer so notified.

SECTION 11—STEEL FORGINGS

Process

1101. Steel for forgings shall be made by either or both of the following processes: open-hearth or electric-furnace.

Discard

1102. A discard shall be made from each ingot sufficient to secure freedom from injurious piping and undue segregation.

Prolongation for Tests

1103. Unless otherwise specified, not less than 20 per cent. of the forgings shall be provided with prolongations for test purposes or, at the manufacturer's option and expense, a forging may be selected.

Annealing

1104. Forgings shall be annealed. The procedure in annealing shall be as follows: Allow the objects, immediately after forging, to cool to a temperature below the critical range under suitable conditions to prevent injury by too rapid cooling; then reheat uniformly to the proper temperature to refine the grain (a group thus reheated being known as an annealing charge) and allow to cool uniformly.

Chemical Composition

1105. The steel shall conform to the following requirements as to chemical composition:

Manganese, per cent	0.40–0.80
Phosphorus, per cent.	
Acid	Not over 0.05
Basic	Not over 0.05
Sulphur, per cent	Not over 0.05

Ladle Analyses

1106. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus, and sulphur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the Engineer, and if it does not conform to the requirements of Article 1105, the melt shall be rejected.

Check Analyses

1107. An analysis may be made by the Engineer from a forging representing each melt. The chemical composition thus determined shall conform to the requirements of Article 1105. Drillings for analysis may be taken from the forgings or from a full-size prolongation thereof, at any point midway between the center and the surface of solid forgings, and at any point midway between the inner and the outer surfaces of the wall of bored forgings; or turnings may be taken from a test specimen.

Physical Properties

1108. The forgings shall conform to the following requirements as to physical properties:

Tensile Strength, minimum, lb. per sq. in. 60,000
Yield point, minimum, lb. per sq. in. ..... 0.5 tens. str.
but not less than 33,000

Elongation in 2 in., minimum, per cent.:

Not over 12 in. diam. ..... $\frac{1{,}700{,}000}{\text{tens. str.}}$ not under 25

Over 12 in. to 20 in. diam., incl. ..... $\frac{1{,}600{,}000}{\text{tens. str.}}$ not under 24

Reduction of area, min., per cent.:

Not over 12 in. diam. ..... $\frac{2{,}700{,}000}{\text{tens. str.}}$ not under 38

Over 12 in. to 20 in. diam., incl. ..... $\frac{2{,}520{,}000}{\text{tens. str.}}$ not under 36

The classification of the forgings as to size shall be determined by the specified diameter or thickness which governs the size of the prolongation from which the test specimen is taken.

Yield Point

1108a. The yield point shall be determined by the drop of the beam or the halt in the gage of the testing machine. The speed of the machine shall conform to the requirements of Article 809.

Tests of forgings shall be made only after the final treatment.

Tension Test Specimens

1109. Tension test specimens shall be taken from a full-size prolongation of the forging. For forgings with large ends or collars the prolongation may be of the same cross-section as that of the forging back of the large end or collar. Specimens may be taken from the forging itself with a hollow drill, if approved by the Engineer.

The axis of the specimen may be located at any point midway between the center and the surface of solid forgings, and at any point midway between the inner and the outer surfaces of the wall of bored forgings, and shall be parallel to the direction in which the metal of the forging is most drawn out.

The specimens shall conform to the dimensions shown in Fig. 5, Article 815.

Number of Tests

1110. Tests shall be made as follows:

One tension test shall be made from each annealing charge. If more than one melt is represented in an annealing charge one tension test shall be made from each melt.

If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

Retests

1111. A retest shall be allowed if the percentage of elongation of any specimen is less than that specified in Article 1108 and if, in addition, any part of the fracture is more than ¾ inch from the center of the gage length, as indicated by scribe marks made on the specimen before testing.

If the results of the physical tests of any test lot of forgings do not conform to the requirements specified, the manufacturer may re-anneal such lot one or more times and retests shall be made as specified in Article 1110.

Finish

1112. The forgings shall be free from injurious defects. The finish shall be workmanlike.

Identification Marks

1113. Identification marks shall be stamped legibly on each forging and on each test specimen.

Inspection

1114. The Inspector shall be allowed free access, while work on the contract of the Company is in progress, to the parts of the works used in the manufacture of the material ordered. The manufacturer shall, without charge, afford the Inspector facilities for making the inspection and furnish the test specimens required, and the testing machines, tools, and labor necessary to make the tests.

Inspections and tests (except check analyses) shall be made at the place of manufacture before shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

1115. Unless otherwise agreed, any rejection based on check analyses shall be reported within five working days from the receipt of the samples.

Specimens representing material rejected as the result of check analyses, shall be preserved for two weeks from the date of the report. In case of dissatisfaction with the result, the manufacturer shall be allowed a rehearing within that time.

Material in which any injurious defect is found after its acceptance at the works will be rejected and the manufacturer so notified.

SECTION 12—CAST STEEL

Process

1201. Cast steel shall be made by one or more of the following processes: Open-hearth, electric-furnace, converter, or crucible.

Annealing

1202. Castings shall be annealed. The procedure in annealing shall be as follows: Allow the castings to cool, after pouring, to a temperature below the critical range, then reheat to the proper temperature and for the required time, to refine the grain, and allow to cool slowly in the furnace until the pyrometer shows that the furnace temperature has fallen to 500° Fahr. The furnace temperature shall be controlled effectively with pyrometers.

Chemical and Physical Properties

1203. Test specimens of cast steel shall conform to the following requirements as to chemical composition and physical properties:

Phosphorus, maximum, per cent	0.05
Manganese, per cent	0.50 to 1.00
Silicon, per cent	0.20 to 0.75
Sulphur, maximum, per cent	0.06
Tensile strength, minimum, lb. per sq. in.	70,000
Yield point, minimum, lb. per sq. in.	38,000
Elongation in 2 inches, minimum, per cent	24
Reduction of area, minimum, per cent	36

Ladle Analyses

1204. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, silicon, phosphorus, and sulphur. This analysis shall be made from drillings taken at least ¼ inch beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the Engineer and if it does not conform to the requirements of Article 1203, the melt shall be rejected.

Check Analyses

1205. Check analyses may be made by the Engineer from a broken tension test specimen or from a casting representing each melt. The chemical composition thus determined shall conform to the requirements of Article 1203. Drillings for analysis shall be taken not less than ¼ inch beneath the surface.

Yield Point

1206. The yield point shall be determined by the drop of the beam or the halt in the gage of the testing machine at a cross-head speed not exceeding ⅛ in. per minute. The tensile strength shall be determined at a cross-head speed not exceeding 1½ in. per minute.

Test Specimens

1208. Tension test specimens shall be taken from test bars cast attached to the castings where practicable. If, in the judgment of the manufacturer, the design of the castings is such that test bars attached directly to the castings might affect the castings or the test specimens injuriously, the test bars shall be cast attached to special blocks. Test bars from which tension test specimens are to be taken shall remain attached to the castings or blocks through annealing and until presented for inspection. Test bars shall be provided in sufficient numbers to furnish the tests required in Article 1211.

1209. Tension test specimens shall conform to the dimensions shown in Fig. 5, Article 815.

Number of Tests

1211. One tension test shall be made from each melt in each annealing charge and, when specified, from each casting weighing 500 pounds or more.

1212. If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen from the same lot substituted.

Retests

1213. A retest shall be allowed if the percentage of elongation of any specimen is less than that specified in Article 1203 and if, in addition, any part of the fracture is more

than ¾ inch from the center of the gage length, as indicated by scribe marks made on the specimen before testing.

1214. If the results of the physical tests of any lot do not conform to the requirements, the manufacturer may re-anneal such lot not more than twice and retests shall be made as specified in Article 1211.

Workmanship and Finish at Foundry

1215. The castings shall conform substantially to the drawings and shall be made in a workmanlike manner. The castings shall be free from injurious defects.

Identification Marks

1216. The name or brand of the manufacturer and the melt number shall be stamped legibly on the finished castings. The melt number shall be marked legibly, by stamping if practicable, on each test specimen.

Inspection

1217. The Inspector shall be allowed free access, while work on the contract of the Company is in progress, to the parts of the works used in the manufacture of the material ordered. The manufacturer shall, without charge, afford the Inspector facilities for making the inspection and furnish the test specimens required, and the testing machines, tools, and labor necessary to make the tests.

Inspections and tests (except check analyses) shall be made at the place of manufacture before shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

1218. Unless otherwise agreed, any rejection based on check analyses shall be reported within five working days from the receipt of the samples.

Specimens representing material rejected as the result of check analyses shall be preserved for two weeks from the date of the report. In case of dissatisfaction with the result, the manufacturer shall be allowed a rehearing within that time.

Material in which any injurious defect is found after its acceptance at the works will be rejected and the manufacturer so notified.

SECTION 13—CAST IRON

Process

1301. Cast iron shall be gray iron made by the cupola process.

Finish

1302. Castings shall be true to pattern and free from excessive shrinkage. They shall be free from cracks, cold shuts, blow holes, and other flaws.

Chemical Composition

1303. The sulphur content of cast iron shall not exceed:

For light castings	0.10 per cent.
For medium castings	0.10 per cent.
For heavy castings	0.12 per cent.

Drillings taken from the fractured ends of the transverse test bars shall be used for the sulphur determinations. One determination shall be made from each of the two sets of test bars representing a melt.

Classification

1304. Castings shall be classified as light, medium, and heavy.

(a) Light castings are those with any section less than ½ inch thick.

(b) Heavy castings are those with no section less than two inches thick.

(c) Medium castings are those not included in either of the classes (a) or (b).

Test Bars

1305. Transverse tests shall be made on the "Arbitration Test Bar" of the American Society for Testing Materials, Serial Designation A–124–29.

Two sets of two bars each shall be made from each melt, one set from the first iron poured and the other set from the last iron poured. If the melt exceeds 20 tons, an additional set of two bars shall be cast from each additional 20 tons or fraction thereof. Each set of two bars shall be cast in a single mold.

Transverse Tests

1306. A transverse test of each bar shall be made. The bar shall be placed on supports spaced 18 inches apart and a load applied at the center.

The application of the load shall be at a rate that will produce a central deflection of 0.10 inch in from 20 to 40 seconds.

One bar of each set shall conform to the following minimum requirements, otherwise the melt shall be rejected:

	Class of Casting		
	Light	*Medium*	*Heavy*
Load at center, pounds	1,500	1,750	2,000
Deflection at center, inch	0.20	0.20	0.20

Inspection

1307. The Inspector shall be allowed free access, while work on the contract of the Company is in progress, to the parts of the works used in the manufacture of the material ordered. The manufacturer shall, without charge, afford the Inspector facilities for making the inspection and furnish the test specimens required, and the testing machines, tools, and labor necessary to make the tests.

Inspections and tests (except check analyses) shall be made at the place of manufacture before shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

PART III—ALLOY STEELS

Foreword

In issuing specifications for using alloy steels in railway bridges, the Committee deems it desirable to present in a Foreword thereto certain information, not appropriate as specification clauses but worthy of consideration when the use of an alloy steel is contemplated.

1. Nickel and silicon steels both have been used in important railway and highway bridges and have proved satisfactory. Other alloy steels have been used successfully.

2. Silicon steel can be obtained from practically all structural and plate mills, even in moderate tonnages if not ordered in too great a variety of sections. Nickel steel can be had by special arrangements with the mill and in larger tonnages; other alloys only by negotiation with the mills.

3. It is customary to use carbon steel rivets in fabricating alloy steels, the rivet values being based on the carbon rivet. In rare instances alloy steel rivets have been used with alloy steels. Studies are now going forward in the American Society for Testing Materials to develop specifications for rivet steels of strength suitable for economical use with alloy steels.

4. The modulus of elasticity is the same for the alloy steels as for carbon steel.

5. Short spans can be constructed most economically of carbon steel.

6. As span lengths increase and the influence of dead load becomes preponderant, a span of equal cost as between carbon steel and part alloy steel will be reached, but of two spans of equal cost in place, the heavier one (carbon steel) is the better purchase, for reasons of rigidity and thickness of material (resistance to corrosion).

7. With increasing length of span, the economy in use of alloy steel will become pronounced and the features of rigidity and resistance to corrosion will be amply protected in an alloy steel design. For such spans, and unless there is extreme need for reducing the dead load, the floor systems should be of carbon steel.

8. Nickel and silicon steels are excellent bridge steels, but it must be remembered that in every high-strength steel, whether high-carbon or alloy, some desirable property must be encroached upon to secure the added strength. While such steels have ample plastic action between yield point and ultimate strength, it is not as great as for carbon steel. While they have excellent ductility and bending properties, those properties are not quite so good as in carbon steel. Therefore, when such steels are used some effort should be made to compensate in the design and details for these differences. For that reason, the allowable unit stresses in these specifications are a somewhat smaller fraction of the specified yield point than those for carbon steel and slightly greater edge distances are desirable.

9. In considering other alloy steels as they are made available, tests should be made to develop the effect of rivet holes and riveting, before determining the allowable unit stresses. No steel should be considered satisfactory for bridge construction if its yield point exceeds 70 per cent. of the ultimate strength.

SECTION 14—ALLOY STEELS

General

The term "Alloy Steel" means structural silicon steel or structural nickel steel.

The foregoing specifications shall apply to alloy steel parts of bridges except as provided otherwise herein.

Unit Stresses

Unit Stresses

1401. The allowable unit stresses to be used in proportioning the parts of a bridge shall be as follows:

	Pounds per Square Inch	
	Silicon Steel	*Nickel Steel*
Axial tension, net section	24,000	27,000
Stress in extreme fibers of rolled shapes, girders, and built sections, subject to bending, net section	24,000	27,000
Axial compression, gross section, for values of $\frac{l}{r}$ not greater than 130: (see note)		
For riveted ends	$20{,}000 - 0.46\frac{l^2}{r^2}$	$22{,}500 - 0.57\frac{l^2}{r^2}$
For pin ends	$20{,}000 - 0.61\frac{l^2}{r^2}$	$22{,}500 - 0.76\frac{l^2}{r^2}$

NOTE.—For values of $\frac{l}{r}$ greater than 130 and for columns of known eccentricity, see Appendix A.

Compression in extreme fibers of rolled shapes, girders, and built sections, subject to bending, for values of $\frac{l}{b}$ not greater than 40, gross section	$24{,}000 - 6.67\frac{l^2}{b^2}$	$27{,}000 - 7.50\frac{l^2}{b^2}$
Stress in extreme fibers of pins	36,000	40,000
Shear in plate girder webs, gross section	14,000	16,000
Shear in pins	18,000	20,000
Bearing on pins, outstanding legs of stiffener angles, and other steel parts in contact	36,000	40,000
Bearing on rocker pins	12,000	13,000
	Pounds per Linear Inch	
Bearing on expansion rollers and rockers	$800d$	$900d$

d = diameter of roller or rocker, in inches.

Thickness of Material

1402. Metal, except for fillers, shall be not less than ⅜ inch thick. Silicon steel plates shall be not more than 1⅛ inches thick and nickel steel plates not more than 1 inch.

In compression members consisting of segments connected by cover plates or lacing, or segments connected by webs, the thickness of the webs of the segments shall be not less than 1/28 of the unsupported distance between the nearest rivet lines. The thickness of the cover plates or webs connecting the segments shall be not less than 1/36 of the unsupported distance between the nearest lines of their connecting rivets or the roots of their rolled flanges.

The thickness of the webs of plate girders shall be not less than 1/145 for silicon steel and 1/140 for nickel steel, of the clear distance between flange angles or side plates.

1402a. If the depth of the web between flanges or side plates of a plate girder exceeds 50 times its thickness, it shall be stiffened by pairs of angles riveted to the web in accordance with the requirements of Article 433.

Sizes of Rivets

1403. The diameter of rivets in main members preferably shall be not less than 1 inch.

Lacing

1404. In compression members, the shearing stress normal to the member in the plane of the lacing shall be that obtained by the following formula:

$$V = \frac{P}{100}\left(\frac{100}{\frac{l}{r} + 10} + \frac{\frac{l}{r}}{70}\right)$$

V = normal shearing stress.
P = allowable compressive axial load on member.
l = length of member, in inches.
r = radius of gyration of section about the axis perpendicular to plane of lacing, in inches.

To the shear so determined shall be added any shear due to the weight of the member or other forces, and the lacing proportioned for the combined shear.

Rivets

1406. Silicon steel and nickel steel shall not be used for rivets. Rivets preferably shall be made of the rivet steel specified in Section 8. Other steels may be used for rivets and bolts if specified by the Engineer.

Alloy and Structural Steels Combined

1407. In case the deformation of alloy steel elements of members or spans induces stresses in other elements exceeding the allowable stresses for structural steel, such other elements also shall be made of alloy steel. Otherwise, bracing and secondary truss members generally shall be made of structural steel. Lacing, stay plates, diaphragms, stiffening angles, and other detail material except gussets and splice plates shall be made of structural steel. For alloy steel elements, the workmanship shall be that specified for alloy steel.

Secondary Stresses

1408. The design and details shall be such that secondary stresses will be as small as practicable. In trusses, secondary stresses due to truss distortion need not be considered in any member, the width of which, measured parallel to the plane of the truss, is less than one-tenth of its length. If the secondary stress exceeds 5,600 pounds per square inch for tension members and 4,200 for compression members, then the excess over 5,600 pounds per square inch for tension members, and 4,200 for compression members shall be treated as a primary stress.

Workmanship

Holes

1409. Alloy steels shall be either drilled or sub-punched and reamed. Silicon steel more than ¾ inch thick and nickel steel more than ⅝ inch thick shall be drilled. The holes may be drilled 1/16 inch larger than the nominal diameter of the rivet or sub-drilled and reamed to that size. Material of less thickness may be either drilled as specified above, or else punched 3/16 inch smaller than the nominal diameter of the rivet and reamed to the finished size.

Planing Sheared Edges

1410. Sheared edges of alloy steel shall be planed to a depth of ¼ inch.

Appendix A

COLUMN FORMULAS

The parabolic formulas for axial compression given in Articles 301 and 1401 fit the values obtained by the secant formula so closely that they may be used without substantial error for slenderness ratios within the limits shown.

The corresponding secant formulas are:

For riveted ends. $$p = \frac{\frac{y}{f}}{1 + 0.25 \text{ Sec.} \frac{0.75\, l}{2r} \sqrt{\frac{fp}{E}}}$$

For pin ends. $$p = \frac{\frac{y}{f}}{1 + 0.25 \text{ Sec.} \frac{0.875\, l}{2r} \sqrt{\frac{fp}{E}}}$$

The coefficient 0.25 in the denominator is the eccentric ratio, $\frac{ec}{r^2}$. It provides for the ordinary amount of crookedness and end eccentricity.

For columns centrally loaded, and having a slenderness ratio beyond the limit fixed for the parabolic formulas, one of the secant formulas above should be used.

For columns with known eccentricity of loading, the following formulas should be used for all slenderness ratios.

For riveted ends. $$p = \frac{\frac{y}{f}}{1 + \left(\frac{ec}{r^2} + .001 \frac{l}{r}\right) \text{Sec.} \frac{0.75\, l}{2r} \sqrt{\frac{fp}{E}}}$$

For pin ends. $$p = \frac{\frac{y}{f}}{1 + \left(\frac{ec}{r^2} + .001 \frac{l}{r}\right) \text{Sec.} \frac{0.875\, l}{2r} \sqrt{\frac{fp}{E}}}$$

p = allowable compressive unit stress.
l = length of member, in inches.
r = least radius of gyration of member, in inches.
c = distance from neutral axis to extreme fibre, in inches.
e = known eccentricity of applied load, in inches.
E = modulus of elasticity = 29,400,000.
y = yield point in tension:
33,000 for structural steel.
45,000 for silicon steel.
50,000 for nickel steel.
f = factor of safety based on yield point:
1.76 for structural steel.
1.80 for silicon steel.
1.78 for nickel steel.

REPORT OF COMMITTEE XXVI—STANDARDIZATION

J. C. Irwin, *Chairman;*
Lem Adams,
H. Austill,
R. C. Bardwell,
E. H. Barnhart,
F. L. C. Bond,
J. G. Brennan,
W. J. Burton,
A. P. Crosley,
Geo. S. Fanning,
J. R. W. Ambrose, *Vice-Chairman;*
P. M. Gault,
C. J. Geyer,
C. C. Haire,
M. J. J. Harrison,
M. Hirschthal,
C. R. Knowles,
J. A. Lahmer,
F. R. Layng,
J. M. Metcalf,
Louis Yager, *Vice-Chairman;*
F. L. Nicholson,
Arthur Ridgway,
G. A. Rodman,
F. C. Shepherd,
Earl Stimson,
W. C. Swartout,
J. E. Teal,
W. M. Vandersluis,
A. R. Wilson,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully presents herewith report covering the following assignments:

1. Encourage the use of A.R.E.A. recommended practices and consider subjects for recommendation to the Board of Direction for sponsoring as projects for National Standardization.

2. Maintain contact with Standardization bodies and keep the Association informed on important matters developed by such contact.

On the first assignment, important progress has been made during the year through contacts with the staff of the Federal Coordinator of Transportation, and specifically with the Section of Purchases, R. L. Lockwood, Director. These contacts began soon after the appointment of the Federal Coordinator and the creation of his organization.

The assurances, early received, that the Coordinator and his staff recognized the value of A.R.E.A. Recommended Practices and the experience and skill of the men responsible for them and proposed to aid in the extension of their use rather than to endeavor to create new ones, were welcomed by this Committee as the most far-reaching support the Association could have in the encouragement of the use of its Recommended Practices.

Mr. Lockwood's first effort was to find out what items that involve the greatest expenditure had been accepted as standards or were in shape for early submission as standards in the railway field. The most conspicuous items were the rail sections, the 131-lb. section having been adopted in the March, 1933, Convention, and the 112-lb. section having been adopted by letter-ballot in the summer of 1933. These sections, adopted as recommended practice, were submitted to the A.R.A. for endorsement. Action on these sections raised the question of the possibility of securing uniformity in joint bars, tie plates, and other track material to go with them. Progress on these items will be reported by the respective standing committees.

The chief function of this Committee has been to furnish information as to the status and to arrange for contacts which would promote an understanding of the situation with a view to advancing new subjects toward standardization beyond the adoption by the A.R.E.A. as recommended practice.

In view of this progressing situation, it was considered most effective to have a meeting of this Committee in Chicago in the fall and invite Mr. Lockwood to outline the policies of the Coordinator, and also to invite President Wiltsee and the other members of the Board of Direction and representatives of other Divisions of the A.R.A. to attend, thus avoiding duplication of effort, promoting understanding and securing cooperation between the Engineering Division and other Divisions of the A.R.A. In order

to make this meeting complete, President Wiltsee, as Chairman of the General Committee of the Engineering Division, called a meeting of that Committee for the same day and arranged for a joint session of that Committee and Committee XXVI—Standardization. This meeting was held October 6th, 1933, at the Palmer House, Chicago.

The joint session was attended by 56 men. President Wiltsee presided, outlined the new aspects of standardization and presented R. L. Lockwood, Director, Section of Purchases, Federal Coordinator of Transportation.

Mr. Lockwood explained how the organization of the Coordinator was set up under the General Enabling Act, the appointment of three Regional Directors and the work of the various sections, and, specifically, of his activities as Director of the Section of Purchases. He emphasized the need for greater simplification through the reduction of sizes and varieties of products and the coordination of standardizing bodies. He stated that it is not the policy of the Coordinator to set up an organization to create standards and that they preferred to put the seal of approval on an accepted fact, and would rely on the expert knowledge and experience represented by A.R.E.A. committees. He spoke of the situation on standards for rail, joint bars, other track material and lumber. He stated that the Coordinator's first press release had to do with materials purchased by the railroads whether purchased directly as commodities or as material furnished by contractors.

The meeting of Committee XXVI—Standardization, which followed this joint meeting, also was attended by Mr. Lockwood and his assistants, George A. Cooper and C. W. Brown, by the President and members of the Board of Direction, and by representatives of other Divisions of the A.R.A. At this meeting, the status of subjects for which National Standardization is considered desirable, was discussed, each member of the Committee, reporting as Chairman of a standing committee, on the status of such subjects under the jurisdiction of his Committee, general discussion following. The situation in regard to subjects being specifically advanced toward National Standardization is described under other sections of this report.

This Committee again emphasizes the fact that benefits of simplification through reduction of the number of types and sizes of materials and the standardization of the remaining types and sizes, can be secured only by setting aside objections due to small personal preferences and joining in with what the majority approves as recommended practices, these, in cases where wide interests are involved and where the economies warrant, to be advanced beyond the immediate railway field, as American Standards, for the use of all industries concerned.

This Committee also again requests members who find real objections to A.R.E.A. Recommended Practices, the use of which involves other interests as well as their own, to notify the Chairman of the A.R.E.A. Committee having jurisdiction over the portion of the Manual concerned, clearly stating the reasons for their objections so that the matter may be duly considered in connection with "Revision of Manual".

SUBJECTS RECOMMENDED FOR NATIONAL STANDARDIZATION

The status of subjects reported by the Committee, under this heading, last year is as follows:

Specifications for Creosote for Wood Preservation

Committee XVII—Wood Preservation, in its report this year, will submit to the Association for approval, revisions of A.R.E.A. specifications resulting from its joint work with the American Wood Preservers' Association and the American Society for

Testing Materials, which, if adopted, will practically establish uniform specifications for Creosote and for Creosote Coal-Tar. These specifications, if endorsed by the A.R.A. and sponsored by these associations as projects of the A.S.A., will be in a position for advancement as American Standards through procedure of the A.S.A.

Specifications for Trolley Wire and Messenger Wire

Projects under this heading are developing through the American Society for Testing Materials, the American Transit Association and the Electrical Standards Committee of the A.S.A. The specifications for both copper and bronze trolley wire, already approved by the A.S.T.M. and the Electrical Section—A.R.A., are being handled under regular procedure of the A.S.A. and are progressing toward final adoption as American Standards. There appears to be no occasion for any action by this Association for their advancement.

Wire and Sheet Metal Gages

This has been accepted as a project of the A.S.A. and is listed as B 32 P. This Committee reported the status last year and has made inquiries during the year. It appears that, for the lack of continuous support of its present sponsors, the project is making no progress. It has been suggested that the A.R.A. and possibly another Association take over the sponsorship and revive the work. This Committee has in progress inquiries as to the exact status and history of the project and what would be involved in carrying it through. The American Society of Mechanical Engineers and the Society of Automotive Engineers have sponsored the inauguration of the project but apparently they desire some other group to assume actual leadership.

At the meeting of this Committee held in Chicago, October 6th, 1933, W. M. Vandersluis, Chairman, Committee XVIII—Electricity, and J. E. Saunders, Chairman of the Signal Section, agreed that something should be done to develop comprehensive up to date wire tables. Other industries, notably, informally, representatives of the International Harvester Company of Canada, Ltd., have referred to the need for a uniform designation of wire sizes, and have made suggestions for a decimal system of numbering. Both the Signal Section and Division I—Operating, T.&T. Section, have representatives of record on the A.S.A. Sectional Committee on this project.

This Committee will continue to collect the necessary information to present to our Board of Direction with recommendations for action to be taken.

Grading Rules and Dimensions of Lumber

This subject was presented in the meeting of this Committee in New York, May 20th, 1932, as one deserving study for National Standardization. The report of this Committee last year (Bulletin 351), included a statement in regard to the organizations working on lumber Standards and the procedure by which "American Lumber Standards" are issued by the Division of Simplified Practice, National Bureau of Standards. Record is made of the acceptances of these "Standards".

The current lumber standards of this character cover only softwoods (conifers). These are as follows:

"Simplified Practice Recommendation R16–29," issued in 1929, covering softwoods in general, with appendices on moldings and red cedar shingles.

"Supplement to Simplified Practice Recommendation R16–29", issued in 1933, further covering moldings and shingles.

The A.R.E.A. is recorded as an acceptor of both of these lumber standards. The former are largely incorporated in A.R.E.A. Manual beginning with "Grading Rules and Classification of Timber and Lumber for Railway Uses", on page 472. However, there appear to be difficulties in the application of these rules and classifications to the purchasers specifications and this situation is now under investigation. It seems probable that Consumer representation of broader scope than is had in the present processes, especially by increased representation from large consumer industries such as the railways, would promote more general understanding and would produce results more readily available for the purchaser.

This subject being brought under discussion at the meeting of this Committee in Chicago, October 6th, views that the present situation is unsatisfactory and requires clarification were expressed by H. Austill, Chairman, Committee VII—Wooden Bridges and

Trestles, W. T. Dorrance, member and former Chairman, Committee VI—Buildings, and Dr. Hermann von Schrenk, Consulting Timber Engineer, member Committee XVII—Wood Preservation and Director A.R.E.A. There were no objectors to this view. As a result of this discussion it was unanimously voted that this Committee recommend to the Board of Direction, A.R.E.A., that this subject be advanced as a project for the American Standards Association. It is being prepared with that recommendation in view. In this connection, the status of the present Simplified Practice Recommendations and their acceptance by the trade and consumers, and their use in the Lumber Code Authority issued under Executive Order are recognized. For the future, the work may lead to greater adaptation to the use of the purchaser and a more extensive participation by consumer interests, in new projects.

Additional subjects suggested by members of this Committee, at its meeting October 6th, for consideration for National Standardization are:

1. Galvanized Culvert Pipe (Geo. S. Fanning, Committee I—Roadway). This subject is being further developed by Committee I and is not yet ready for action by this Committee.
2. Track Scales (J. R. W. Ambrose, Vice-Chairman and M. J. J. Harrison, Committee XIV—Yards and Terminals).
   Discussion developed the fact that certain phases of this subject appear to be ready for recommendation for advancement and, at the meeting of Committee XIV, held October 9th and 10th, 1933 (subsequent to the meeting of this Committee), the following action was taken.
   "It was voted to recommend, on behalf of the Yards and Terminals Committee, the specifications for Two and Four-Section Track Scales for Standardization by the American Standards Association".
   This action of the Yards and Terminals Committee will be submitted to the full membership of this Committee with a view to recommendations to the Board of Direction. It refers to specifications in the Manual as follows:
   Pages 1008 to 1026—Specifications for the Manufacture and Installation of Four-Section Railway Track Scales. (For Knife-Edge Scales only, not Including Overhead Suspension Scales). These specifications have been promulgated by the National Bureau of Standards as its Circular No. 83.
   Pages 1050 to 1067—Specifications for the Manufacture and Installation of Two-Section Knife-Edge Railway Track Scales. These specifications have been promulgated by the National Bureau of Standards as its Circular No. 333.
   The history of these projects has been submitted by Mr. Harrison.
3. Tank Hoop Lugs (R. C. Bardwell, Committee XIII—Water Service and Sanitation).
   Mr. Bardwell called attention to difficulty in securing lugs as adopted by A.R.E.A. (Manual pages 940, 941). This difficulty apparently is due to the influence of the use of lugs, not conforming to A.R.E.A. recommended practice, by interests other than the railways. The subject will be investigated further to see whether the desired results should be obtained merely by demanding A.R.E.A. requirements or by endeavoring to bring about national standards conforming to them.

This Committee directs attention to the "Electrical Section Reports," Bulletin 359, page 42, Committee VII—Standardization of Apparatus and Materials, Sidney Withington, Chairman, with special reference to work under way as projects of the American Standards Association.

STATUS OF A.R.A. RECOMMENDED STANDARDS FOR RAILROAD HIGHWAY GRADE CROSSING PROTECTION

This report of the Standardization Committee affords the medium for information to this Association of the progress in establishing uniform methods of protection for highways crossing railways at grade. Frank Ringer, former Director, Chairman of the

Joint Committee on Grade Crossing Protection, A.R.A., furnishes the following statement from his Committee.

"The Joint Committee on Grade Crossing Protection has continued to cooperate with the Railroad and Highway Commissions of the several states, upon request of the latter, and has furnished information that would be of service in determining their policy with respect to highway grade crossing protection.

"During the past year Utah and Missouri have, by Commission Order, adopted standards for grade crossing protection substantially in accord with American Railway Association recommended practice. Several states, among which are Connecticut, Massachusetts and Pennsylvania have approved installations of signals that conform to A.R.A. standards, and others are giving consideration to their use.

"The National Association of Railroad and Utilities Commissioners at their 1932 annual convention approved a committee report which included an endorsement of standards and practices as outlined in Bulletin No. 1. An invitation to attend the 1933 convention has been extended to the membership of the Joint Committee.

"The National Conference on Street and Highway Safety and the American Association of State Highway Officials over a year ago appointed a joint committee to recommend standards for highway signs and markings. This committee, upon which the Joint Committee on Grade Crossing Protection was represented, has recently presented a report which embodies a recommendation that A.R.A. standards be used.

"It is believed the railroads in general are showing an increased trend towards the use of uniform protection at grade crossings. Progress towards complete standardization must of a necessity come through a definite policy on the part of all carriers concerned. Such a policy, insofar as the various signs and signals are concerned, is set forth in our Bulletin No. 1. A gradual realization of this purpose is indicated."

American Railway Association,
Joint Committee on Grade Crossing Protection.
Washington, D. C.
October 11, 1933.

AMERICAN STANDARDS ASSOCIATION (A.S.A.)

A.R.A. Representation in A.S.A.

Members of the Board of Directors
L. A. Downs (Elected as A.R.A. Representative)
J. C. Irwin (Ex-Officio, as Chairman, Standards Council)
Members of the Standards Council
Representative, Div. I —Operating; W. Rogers (term expires December 31, 1934)
" Div. IV—Engineering; J. C. Irwin (" " " 31, 1936)
" Div. V —Mechanical; W. I. Cantley
(term expires December 31, 1935)
Alternates J. R. W. Ambrose
E. K. Post
J. S. Hagan
J. E. Saunders
L. C. Thomson

Relations between A.S.A. and National Bureau of Standards

The U.S. Department of Commerce, of which the Bureau of Standards is a part, is one of the Member Bodies of the A.S.A. Dr. Lyman J. Briggs, Director, National Bureau of Standards, is a Director of the A.S.A. and the Bureau has three Representatives and three Alternates on the Standards Council, A.S.A. Other U.S. Departments having membership in the A.S.A. and Representatives and Alternates on the Standards

Council are the Departments of Agriculture, Interior, Labor, Navy, War, the Government Printing Office and the Panama Canal. The Government, therefore, is participating very fully in the work of the A.S.A.

As stated in previous reports of this Committee, particularly in its report of November, 1931, Vol. 33, the Bureau of Standards has done very extensive work on simplification and standardization by bringing together the various interests involved in any industrial line and publishing the results of conferences as Simplified Practice Recommendations.

Early in the summer of 1933, Secretary of Commerce Daniel C. Roper, notified the President of American Standards Association, Howard Coonley, that the Bureau of Standards was discontinuing most of the work which it had been carrying on in the field of simplification, commercial standards, safety codes and building codes for the reason that he considered that these functions should be in the hands of industry and consumer groups and that as a result of conferences between Secretary Roper and Mr. Coonley the A.S.A. would be relied on to carry out the essentials of this work with the full cooperation of the Bureau of Standards. It was understood that the transfer of such activities would be made gradually. This arrangement permits of large savings in the Bureau of Standards with much smaller increases in the budget of the A.S.A. as it is organized to handle such work, with some changes. The responsibility was accepted by the Board of the A.S.A. and special committees of the Board of Directors and of the Standards Council were appointed to arrange for the financing and organization for the enlarged scope of the work.

A Conference was held in Washington October 19, 1933, at which all interested parties were invited to express their views on the handling of standardization. Assistant Secretary of Commerce John Dickinson presided. At this Conference Secretary Roper expressed his opinion that "whatever industry can satisfactorily do for itself should no longer be done at the expense of the taxpayer", and that with this view, and the need for economy in government, it was felt that the time had come to invite the American Standards Association to help carry the burden of commercial standardization activity which the government had been carrying. He also cited the A.S.A. as a quasi-governmental activity, because of the membership of seven government departments in A.S.A.

As a result of these preliminary arrangements, "Commercial Standards Monthly", the periodical of the Bureau of Standards, was merged with "Industrial Standardization", the periodical of the A.S.A., beginning with the issue of July, 1933, the merged paper carrying the title "Industrial Standardization and Commercial Standards Monthly". Attention is directed to the issue of July, 1933, with a cover statement by Dr. L. J. Briggs and report and correspondence between Secretary Roper and President Coonley in regard to the transfer of activities, and also to the issue of November, 1933, giving reports of their addresses before the Conference on Standardization held in Washington, October 19th, 1933.

Subsequent developments have led to modifications in the general plan of organization for standardization but with the same objective. A detailed plan for handling the work for the present is being worked out between the A.S.A. and the Bureau.

"Industrial Standardization and Commercial Standards Monthly" of October, 1933, contains valuable articles on Building and Plumbing Codes as follows:

"Building Codes" by George N. Thompson, formerly Chief of the Building Code Section of the National Bureau of Standards.

"The Plumbing Code Situation in the United States" by William C. Groeniger, Chairman, Sectional Committee on Standardization of Plumbing Equipment, American Society of Sanitary Engineering; Consulting Sanitary Engineer, Columbus, Ohio.

"The National Board of Fire Underwriters' Proposed Uniform Building Code" by Clinton T. Bissell, Associate Consulting Engineer, National Board of Fire Underwriters.

"Building Code Developments on the Pacific Coast" by David H. Merrill, Managing Secretary-Treasurer, Pacific Coast Building Officials' Conference, and

"A Uniform Building Code for the Municipalities of New England" by Edward W. Roemer, President, New England Building Officials' Conference; Building Commissioner, City of Boston.

Inch-Millimeter Conversion Tables for Industrial Use

As a result of the adoption of the value 25.4 as the American Standard inch-millimeter ratio for industrial use as reported last year by this Committee, Vol. 33, page 314, conversion tables have been prepared which, together with descriptive matter, are published in a ten-page pamphlet with the title "American Standard Practice for Inch-Millimeter Conversion for Industrial Use". This may be secured at slight expense, varying with the number of copies ordered, from the American Standards Association, 29 West 39th Street, New York, N. Y.

General

This report on the activities of the A.S.A. is supplemented by appendices as follows:

Appendix A—Standards Approved by the American Standards Association, Period September 1, 1932 to September 1, 1933.

Appendix B—American Standards Association Technical Projects on which the Railway Associations are now Cooperating.

CANADIAN ENGINEERING STANDARDS ASSOCIATION (C.E.S.A.)

The following memorandum in regard to C.E.S.A. activities in 1933 up to September 30, is furnished by B. Stuart McKenzie, Secretary.

Civil Engineering and Construction

Work has been confined to an investigation into the situation on building brick sizes. A special panel of the Committee on Building Materials has been gathering information through a questionnaire, and it is hoped shortly to make a definite recommendation for a standard size of building brick for use in Canada, and if this is adopted, to proceed with the standardization of other types of building materials.

Mechanical Engineering

One standard has been issued during the year covering Binder Head Screws used in the electrical trade. After considerable investigation and discussion, agreement was reached on one standard design and six different sizes, which it is believed will effect a most useful simplification in connection with this particular project.

The draft Safety Code for Passenger and Freight Elevators has been prepared and sent out to the committee for comments, and it is hoped shortly to have a meeting to discuss revisions to the first draft.

Preparations are being made to consider standards for Wood Screws and Small Rivets.

The standard for Machine, Carriage and Plow Bolts has been held up waiting for information on certain changes which have been taking place in the trade, but it is hoped that this may possibly be issued before the end of the year. Information is being included in the specification to cover heavy bolts and nuts such as are used in railway practice, but the standard does not include track bolts.

Electrical Work

A rather radical change in the electrical situation in Canada took place at the beginning of the year, when the Underwriters' Laboratories at Chicago practically withdrew from the field in Canada, and approval of electrical apparatus is done almost entirely by the Hydro-Electric Power Commission of Ontario in Toronto. Tests will now be made on specifications prepared by the Canadian Engineering Standards Association, and a label service has been inaugurated. Specifications covering Electric Signs and Electrical Equipment for Oil-burning Apparatus, also a special pamphlet covering Definitions and General Requirements in connection with all approval specifications, have been issued, and specifications for Electric Floor Surfacing and Cleaning Machines and Portable Electric Displays and Incandescent Lamp Signs are being printed. Specifications for Electric Clocks and Electric Fixtures will shortly be issued. Other specifications which have been prepared and are now being discussed cover Enclosed Switches, Service Entrance and Branch Circuit-breakers, Capacitors (Electrical Condensors), Fractional Horsepower Motors, Electric Portable Lighting Devices, Transformers for Luminous-tube Signs and Oil-burner Ignition Equipment, Industrial Control Equipment, Heating Pads, Insulated Conductors for Power-operated Radio Devices, Cable for Luminous-tube Signs and Oil-burner Ignition Equipment, Outlet Boxes, Soldering Lugs, Motor-operated Blowers and Stokers, Cord Sets and Gasoline Measuring and Discharge Devices.

The Third edition of Part I of the Canadian Electrical Code, covering wiring rules, is now being considered.

Committees are working on revisions to the specification for A.C. Watthour Meters, also a new specification for Demand Meters. Consideration is being given to drafts of new specifications for Power Transformers and for Insulating Oils, but it has not been possible to do much work on these during the year. New standards covering Enamelled Magnet Wire, Oil Circuit-breakers, and Insulated Power Cable are being prepared.

The Association has been somewhat handicapped during the year by a falling off of subscriptions from industry, but it has still been possible to carry on fairly satisfactorily and it is hoped that next year will bring a welcomed change.

The Association is now lodged in the National Research Building on Sussex Street, Ottawa, quarters having been provided by the National Research Council of Canada.

Ottawa, September 30, 1933.

Respectfully submitted,

The Committee on Standardization,

J. C. Irwin, *Chairman.*

Appendix A

STANDARDS APPROVED BY AMERICAN STANDARDS ASSOCIATION

Period September 1, 1932 to September 1, 1933

ASA Symbol	*Title*	*Approved as*
Civil Engineering		
A1.2—1933	Methods of Sampling and Testing Portland Cement	American Standard
A23—1932	Code for Lighting of School Buildings	American Standard
A38—1933	Steel Spiral Rods for Concrete Reinforcement	American Standard
A48—1932	Forms for Concrete Joist Construction Floors	American Standard
A49.1—1933	Standard Specifications for Gypsum	American Standard
A49.2—1933	Standard Specifications for Calcined Gypsum	American Standard
A49.3—1933	Standard Specifications for Gypsum Plasters	American Standard
A49.4—1933	Standard Specifications for Gypsum Molding Plaster	American Standard
A49.5—1933	Standard Specifications for Gypsum Pottery Plaster	American Standard
Mechanical Engineering		
B3.1—1933	Annular Ball Bearings, Single Row Type	American Standard
B5.5—1932	Rotating Air Cylinders and Adapters	American Standard
B6.1—1932	Spur Gear Tooth Form	American Standard
B6.2—1933	Gear Materials and Blanks	Amer. Rec. Practice
B9—1933	Safety Code for Mechanical Refrigeration	American Standard
B16e—1932	Steel Flanged Fittings and Companion Flanges	American Standard
B18.2—1933	Wrench Head Bolts and Nuts and Wrench Openings	American Standard
B45.1—1932	Foundry Patterns of Wood	Amer. Rec. Practice
B48.1—1933	Inch-Millimeter Conversion for Industrial Use	American Standard
B49—1932	Shaft Couplings, Integrally Forged Flange Type for Hydro-Electric Units	American Standard
Electrical Engineering		
C5.1—1933	Part I of Code for Protection Against Lightning — covering protection of persons	American Standard
C5.2—1933	Part II of Code for Protection Against Lightning — covering protection of buildings and miscellaneous property	American Standard
C8.10—1933	Specifications for Impregnated Paper Insulation for Lead Covered Power Cables	American Standard
C8.11—1933	Standard Specifications for Code Rubber Insulation	American Standard
C57.1—1933	Standards for Constant Current Transformers	American Standard
Transportation		
E4—1933	Design for 7 inch girder grooved rail	American Standard
E5—1933	Design for 9 inch girder grooved rail	American Standard
E6—1933	Design for 7 inch girder guard rail	American Standard
E7—1933	Design for 9 inch girder guard rail	American Standard
E8—1933	Design for 7 inch, 82 lb. plain girder rail and splice bars for use in paved streets	American Standard
E9—1933	Design for 7 inch, 92 lb. plain girder rail and splice bars for use in paved streets	Amer. Tent. Std.
E11—1933	Design for 7 inch, 102 lb. plain girder rail and splice bars for use in paved streets	Amer. Tent. Std.
Non-Ferrous Metallurgy		
H17.1—1932	Specifications for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars	American Standard
H17.2—1932	Specifications for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars	American Standard
Mining		
M7.1—1933	Frogs, Switches and Turnouts for Coal Mine Tracks	Amer. Rec. Practice
Miscellaneous		
Z7—1932	Illuminating Engineering Nomenclature and Photometric Standards	American Standard
Z10i—1932	Abbreviations for Scientific and Engineering Terms	Amer. Tent. Std.
Z11.5—1932	Cloud and Pour Points	American Standard
Z11.11—1932	Distillation of Natural Gasoline	American Standard
Z11.22—1932	Melting Point of Petrolatum	American Standard
Z11.23—1932	Determination of Autogenous Ignition Temperatures	American Standard
Z11.24—1932	Flash Point of Volatile Flammable Liquids	American Standard

ASA Symbol	*Title*	*Approved as*
Z11.25—1932	Carbon Residue of Petroleum Products	American Standard
Z11.26—1932	Testing Gas Oils	American Standard
Z11.27—1932	Expressible Oil and Moisture in Paraffin Waxes	Amer. Tent. Std.
Z11.28—1932	Definitions of Terms Relating to Petroleum	Amer. Tent. Std.
Z11.29—1932	Dilution of Crankcase Oils	Amer. Tent. Std.
Z11.30—1932	Precipitation Number of Lubricating Oils	Amer. Tent. Std.
Z15.1—1932	Engineering and Scientific Charts for Lantern Slides	Amer. Rec. Practice
Z21.2—1932	Approval Requirements for Flexible Gas Tubing	American Standard
Z21.3—1932	Approval Requirements for Hotel and Restaurant Ranges	American Standard
Z21.4—1932	Approval Requirements for Private Garage Heaters	American Standard
Z21.5—1932	Approval Requirements for Clothes Dryers	American Standard
Z21.6—1932	Approval Requirements for Incinerators	American Standard
Z21.7—1932	Approval Requirements for Gas Heated Ironers	American Standard
Z21.8—1933	Requirements for Installation of Conversion Burners in House Heating and Water Heating Appliances	American Standard
Z27—1933	Recommended Good Practice Requirements for the Installation, Maintenance and Use of Piping and Fittings for City Gas	Amer. Rec. Practice

Appendix B

AMERICAN STANDARDS ASSOCIATION TECHNICAL PROJECTS ON WHICH THE RAILWAY ASSOCIATIONS ARE NOW COOPERATING

	ASA Project	*A.R.A. Div. or Sec. Represented A.R.E.A. (Const. & Maint. Sec.) Committee Contact*	*Members representing Railway Associations*
A1—1931	Portland Cement, Specifications for	IV Eng.—Com. VIII—Masonry	Meyer Hirschthal J. F. Leonard J. J. Yates
A21	Cast Iron Pipe and Special Castings, Specifications for	IV Eng.—Com. XIII—Water Service, Fire Protection and Sanitation	C. R. Knowles Alt.—C. P. Van Gundy
A22	Walkway Surfaces, Safety Code for	IV Eng.—Com. VI—Buildings	Wm. T. Dorrance
A35	Manhole Frames and Covers	I Oper.—T. & T. Sec. IV Eng.—Com. XIV — Yards and Terminals	J. A. Jones H. L. Ripley Alt.—J. R. W. Ambrose Alt.—Wm. T. Dorrance
A36	Rating of Rivers	IV Eng.—Elec. Sec.	R. J. Needham
B1	Screw Threads, Standardization and Unification of	IV Eng.—Com. V—Track —Sig. Sec. V Mech.	J. V. Neubert H. G. Morgan W. I. Cantley Alt.—S. S. Riegel F. M. Waring
B3	Ball and Roller Bearings	V Mech.	W. I. Cantley Alt.—S. S. Riegel F. M. Waring
B4	Cylindrical Parts and Limit Gages, Allowances and Tolerances for	V Mech.	W. I. Cantley F. M. Waring Alt.—S. S. Riegel
B16	Pipe Flanges and Fittings	IV Eng.—Com. XIII—Water Service, Fire Protection and Sanitation	C. R. Knowles
		IV Eng.—Elec. Sec. —Sig. Sec. V Mech.	J. V. B. Duer E. K. Post W. I. Cantley Burton P. Flory
B18	Bolt, Nut and Rivet Proportions	A.R.A.—Rail Com. IV Eng.—Com. V—Track IV Eng.—Com. XV—Iron and Steel Structures V Mech.	Lem Adams J. V. Neubert Alt.—J. B. Myers Philip G. Lang, Jr. Alt.—O. E. Selby J. McMullen C. B. Smith
B19	Standard Code for Work in Compressed Air	I Oper.—Medical & Surgical Sec. IV Eng.—Com. VIII—Masonry	Dr. John McCombe J. J. Yates
B20	Conveyors and Conveying Machinery, Safety Code for	IV Eng.—Com. XXIII—Shops and Locomotive Terminals	Vacant
B27	Plain and Lock Washers	IV Eng.—Com. V—Track V Mech. VI Purchases and Stores	E. W. Caruthers A. H. Fetters H. A. Hoke E. D. Toye Alt.—A. G. Follette
B30	Cranes, Derricks and Hoists, Safety Code for	IV Eng.—Com. XII—Rules and Organization	W. C. Barrett Alt.—M. M. Backus
B32P	Wire and Sheet Metal Gages	I Oper.—T. & T. Sec. IV Eng.—Sig. Sec.	J. A. Jones H. G. Morgan
B33	Screw Threads for Hose Couplings	IV Eng.—Com. XIII—Water Service, Fire Protection and Sanitation	Wesley L. Curtiss Alt.—J. P. Hanley
B36	Dimensions and Materials of Wrought Iron and Wrought Steel Pipe and Tubing, Standardization of	IV Eng.—Com. XIII—Water Service, Fire Protection and Sanitation V Mech.	J. J. Laudig Alt.—W. B. Nissly F. M. Waring
B40P	Pressure and Vacuum Gages, Specifications for	V Mech.	F. M. Waring
B41	Stock Sizes, Shapes and Lengths for Iron and Steel Bars, Including Flats, Squares, Rounds and Other Shapes	V Mech.	H. G. Burnham
B42P	Leather Belting, Specifications for	VI Purchases and Stores	C. L. McIlvaine

	ASA Project	A.R.A. Div. or Sec. Represented A.R.E.A. (Const. & Maint. Sec.) Committee Contact	Members representing Railway Associations
B43P	Machine Pins, Dimensions of	V Mech.	A. H. Fetters H. A. Hoke
C1—1933	Electric Wiring and Apparatus in Relation to Fire Hazard, Regulations for (National Electrical Code)	IV Eng.—Elec. Sec.	George O. Moores Alt.—I. V. Goodman
C2—1927	National Electrical Safety Code Parts I and III	I Oper.—T. & T. Sec. IV Eng.—Elec. Sec. —Sig. Sec.	John Miller J. V. B. Duer H. M. Warren Alt.—L. S. Wells A. H. Rice Alt.—J. B. Lamb
	Parts II and IV	I Oper.—T. & T. Sec. IV Eng.—Elec. Sec. —Sig. Sec.	R. F. Finley W. L. Morse J. V. B. Duer G. H. Dryden
C5	Lightning, Code for Protection Against	I Oper.—T. & T. Sec.	H. C. Land
C8	Wires and Cables, Insulated (Other than Telephone and Telegraph)	IV Eng.—Elec. Sec. —Sig. Sec.	C. B. Martin W. H. Elliott
C8K2—1932	Heat Resisting Wires and Cables	IV Eng.—Elec. Sec.	J. L. Bracken
C10—1924	Electrical Equipment of Buildings, Standard Symbols for	IV Eng.—Elec. Sec.	Vacant
C11—1927	Hard Drawn Aluminum Conductors	IV Eng.—Com. X—Signals and Interlocking —Elec. Sec.	W. H. Elliott F. D. Hall
C16	Radio	I Oper.—T. & T. Sec.	A. R. Belmont
C18—1930	Dry Cells and Batteries, Specifications for	I Oper.—T. & T. Sec. IV Eng.—Sig. Sec.	G. R. Stewart A. B. Himes
C29	Insulators for Electric Power Lines	IV Eng.—Elec. Sec. —Sig. Sec.	G. I. Wright G. W. Chappell
C34	Mercury Arc Rectifiers	IV Eng.—Elec. Sec.	G. I. Wright
C35	Railway Motors	IV Eng.—Com. XVIII—Electricity —Elec. Sec.	H A. Currie Alt.—J. V. B. Duer J. E. Sharpley Alt.—S. Withington
C37	Power Switchgear	IV Eng.—Elec. Sec.	J. S. Hagan
C39P	Electrical Measuring Instruments	IV Eng.—Elec. Sec.	C. J. McCarthy
C42	Electrical Terms, Definitions of	I Oper.—T. & T. Sec. IV Eng.—Elec. Sec.	A. H. Johnson J. H. Davis
C44—1931	Rolled Threads for Screw Shells of Electric Sockets and Lamp Bases	IV Eng.—Sig. Sec. V Mech.	H. G. Morgan H. A. Currie
C50	Rotating Electrical Machinery	IV Eng.—Elec. Sec.	J. V. B. Duer
C52	Electric Welding Apparatus	IV Eng.—Const. & Maint. Sec.	Lem Adams
C57P	Transformers	IV Eng.—Elec. Sec.	B. F. Bardo
C59	Specifications and Methods of Test for Electrical Insulating Materials	IV Eng.—Elec. Sec. —Sig. Sec. V Mech.	C. B. Martin Representative to be appointed. Ditto
C60	Vacuum Tubes for Industrial Purposes	IV Eng.—Elec. Sec.	J. V. B. Duer Alt.—A. D. Whamond
D5	Street Traffic Signs, Signals and Markings, Manual on	IV Eng.—Sig. Sec.	A. H. Rudd
G8	Zinc Coating of Iron and Steel, Specifications for	I Oper.—T. & T. Sec. IV Eng.—Com. I—Roadway	J. A. Jones W. C. Swartout Alt.—C. P. Van Gundy
H4—1928	Soft or Annealed Copper Wire, Specifications for	I Oper.—T. & T. Sec.	J. A. Jones
H14—1929	Hard-Drawn Copper Wire, Specifications for	I Oper.—T. & T. Sec.	J. A. Jones
H15	Medium Hard-Drawn Copper Wire, Specifications for	I Oper.—T. & T. Sec.	J. A. Jones

	ASA Project	*A.R.A. Div. or Sec. Represented A.R.E.A. (Const. & Maint. Sec.) Committee Contact*	*Members representing Railway Associations*
H16—1928	Tinned Soft or Annealed Copper Wire for Rubber Insulation, Specifications for	I Oper.—T. & T. Sec.	J. A. Jones
M7	Coal Mine Tracks, Signals and Switches	IV Eng.—Com. V—Track	C. J. Geyer
M26P	Clean Bituminous Coal, Specifications for	VI Purchases and Stores	C. E. Smith
O3—1926	Cross-ties and Switch-ties, Specifications for	IV Eng.—Com. III—Ties	John Foley
O4	Wood, Methods of Testing	IV Eng.—Com. VI—Buildings	Wm. T. Dorrance Alt.—C. J. Hogue Alt.—J. W. Orrock
O5	Wood Poles, Specifications for	I Oper.—T. & T. Sec. IV Eng.—Elec. Sec.	J. A. Jones Alt.—H. A. Shepard Paul Lebenbaum
Z2	Protection of Heads and Eyes of Industrial Workers, Safety Code for the	I Oper.—Medical and Surgical Sec.	Dr. C. W. Hopkins
Z4	Industrial Sanitation, Safety Code for	I Oper.—Medical and Surgical Sec.	Dr. G. G. Dowdall
Z5P	Ventilation Code	IV Eng.—Com. VI—Buildings V Mech.	W. T. Dorrance Alt.—Wm. J. Madden
Z10	Scientific and Engineering Symbols and Abbreviations	IV Eng.—Sig. Sec. I Oper.—T. & T. Sec.	E. K. Post Alt.—J. V. B. Duer Alt.—A. H. Johnson
Z14	Drawings and Drafting Room Practice (Exclusive of Architectural Drawings), Standards for	IV Eng.—Com. XI — Records and Accounts	D. L. Avery
Z15	Graphic Presentation, Standards for	I Oper.—T. & T. Sec. IV Eng.—Com. XI — Records and Accounts —Sig. Sec.	L. A. Moll D. L. Avery H. G. Morgan
Z16	Methods of Recording and Compiling Accident Statistics Standardization of	I Oper.—Safety Sec.	T. H. Carrow
Z23	Sieves for Testing Purposes, Specifications for	IV Eng.—Com. VIII—Masonry	Meyer Hirschthal
Z26	Safety Code for Specifications and Methods of Tests for Safety Glass	IV Eng.—Const. and Maint. Sec.	J. B. Young

Electrical Standards Committee—Sidney Withington

Sidney Withington is also a member of the U. S. Nat. Committee of the International Electrotechnical Commission—not as an A.R.A. Representative.

DISCUSSIONS

A

DISCUSSION ON UNIFORM GENERAL CONTRACT FORMS

(For Report, see pp. 309-332)

Mr. F. L. Nicholson (Norfolk Southern):—The report of Committee XX will be found in Bulletin 360, page 309.

On the first subject, Revision of Manual, the Committee has no report to make at this time.

On the second subject, Form of Agreement for the Purchase of Electrical Energy in Large Volume (such as required for traction purposes), this subject was assigned to Committee XX at the conclusion of the 1928 convention, and a Form of Agreement was prepared and submitted to Committee XVIII—Electricity. A progress report was made at the 1929 convention.

Shortly after that convention, the Electrical Section of the American Railway Association appointed Committee XVII to collaborate with Committee XX, and since that date there has been the closest possible collaboration in the preparation of this form.

In order that you may know something about the class of help that this Committee has had in the preparation of this form, I will simply remark that the Electrical Engineers of the Delaware, Lackawanna and Western, Illinois Central, New York Central, Atlantic Coast Line, the Baltimore and Ohio, the Pennsylvania Railroad, the New York, New Haven and Hartford, Reading, the Key System, Public Service Company of Northern Illinois, and the Niagara Junction Railway, collaborated with us. They were on Committee XVII of the Electrical Section.

So many differences of opinion arose in the Committee, and so many suggestions were received from prominent members of the National Electric Light Association, now the Edison Electric Institute, that the Committee submitted practically a new draft of agreement for the 1932 convention.

In passing I will say that it is almost impossible to get a trade or an industrial organization as such to endorse a Form of Agreement proposed by this organization. They will collaborate with us; their members will agree on the terms and conditions, but as to getting it, as an organization, to endorse it, is another matter. They feel that such endorsement ties their hands; they cannot enter into agreements with individual railroads if they have agreed to our forms.

In the preparation of the form, the Committee has given most careful consideration to the suggestions submitted by the various interested parties and has freely consulted published works of the American Electric Railway Engineering Association and the Association of Railway Electrical Engineers and will present to you the result of these years of painstaking labor, with the hope that the provisions in the form may meet with your approval for printing in the Manual as recommended practice.

I will ask Mr. W. G. Nusz, Chairman of the Sub-Committee, to present the report.

Mr. W. G. Nusz (Illinois Central):—A joint meeting of the Sub-Committee of Committee XX and the Sub-Committee of Committee XVII of the Electrical Section held this year considered all the comments and suggestions received by your Committee and a draft of the completed Form of Agreement is shown on pages 311 to 319 inclusive. For the purpose of discussion, we will consider the Agreement section by section.

I move the adoption of the Agreement as shown in Bulletin 360, pages 311 to 319 inclusive.

The President:—The question before you is the adoption of the recommendation of this Committee on the Agreement. Inasmuch as that is rather a lengthy Agreement, I

think the Chairman should offer each section by title to the convention and pause a few moments, allowing anybody to offer amendments or discussion.

Mr. W. G. Nusz:—The preamble is on page 311 and the top of page 312.

Article I, Term of Agreement.
Article II, Obligations as to Supply and Purchase.
Article III, Character of Service.
Article IV, Character of Load.
Article V, Points of Delivery.
Article VI, Rates and Payments.
- Section 1. Primary and Secondary Charges.
- Section 2. Determination of Demand.
- Section 3. Right of Railway Company to Examine Records.
- Section 4. Payments, Time when Due.

Article VII, Metering.
- Section 1. Location and Ownership of Meters.
- Section 2. Type of meters and right of railway to be represented at reading and testing of them.
- Section 3. Testing and Adjustment of Meters.

Article VIII, Interruption, Default and Termination.
- Section 1. Reduction in Primary Charge.
- Section 2. Reduction in Secondary Charge.
- Section 3. Termination by Railway Company for Poor Service.
- Section 4. Termination by Railway Company due to Increase in Rates by the Power Company.
- Section 5. Termination by Power Company for Non-Payment of Bills.
- Section 6. Termination by Power Company for Interference to its Service to other Customers.

Article IX, Reduction in Rates.
Article X, Arbitration.
Article XI, General.
- Section 1. Power Company's Right of Access to Railway Company's Property.
- Section 2. Repair and Renewal of Apparatus.
- Section 3. Indemnity Clauses.
- Section 4. Waivers.
- Section 5. Assignments.

The President:—The question before you is on the adoption of the motion to approve this Agreement for printing in the Manual. Is there any further discussion? Are you ready for the question? All those in favor will signify by saying "aye"; contrary. It is carried and so ordered.

Chairman F. L. Nicholson:—The next subject is Form of Conveyance of Title Granting the Right to Construct and Maintain Buildings over Railway Property. Mr. R. P. Eubank is Chairman of the Sub-Committee. The draft is submitted to you as information, and it is hoped that those interested in this subject will carefully review and give the benefit of their views to the Committee.

The President:—The report will be received as information unless there is objection thereto. It is so received.

Chairman F. L. Nicholson:—The next is Form of Agreement for Pipe Line Crossings under Railway Tracks—Appendix D; and Form of Agreement for Use of Railway Property by Pipe Lines Paralleling Railway, with Special Reference to Pipe Lines Carrying High Pressure Inflammable Oils or Gas.

When the Committee began preparation of these forms, it came to the conclusion that one form could and should be prepared to cover both assignments, and the form now presented has been prepared in collaboration with Committee I—Roadway and Committee XIII—Water Service and Sanitation.

I will ask Mr. Miller, Chairman of the Sub-Committee, to present the report.

Mr. A. A. Miller (Missouri Pacific):—Under Appendix D on page 325 of Bulletin 360 will be found the Form of Agreement for Pipe Line Crossings under Railway Tracks and for the Use of Railway Property by Pipe Lines Generally Paralleling the Railway, and it is there indicated that this Committee is submitting the form for your adoption and inclusion in the Manual.

Just recently information has come to this Committee that makes it desirable and advisable that work on this particular form be continued, and this report at this time we suggest be accepted as information.

The President:—The report will be so received unless there is objection to such action, and the subject will be continued.

Chairman F. L. Nicholson:—The next subject is Form of Agreement with Public Authorities for Highway Grade Crossing Elimination or Separation.

This Form of Agreement as prepared and submitted covers both over and underpass grade separation. It is complete. But following the practice of the Committee to give ample opportunity for discussion and suggestions, it is submitted as a progress report with the hope that the members will favor the Committee with such suggestions as they care to make for its betterment, that the Committee may present at the next convention, for adoption, a form that will be most useful to you.

The President:—Is there objection to receiving this as a progress report? Is there any discussion on the subject? The report will be so received.

Chairman F. L. Nicholson:—That completes our report.

The President:—The Committee is relieved with the thanks of the Association for their excellent report (Applause).

DISCUSSION ON YARDS AND TERMINALS

(For Report, see pp. 419–472)

Mr. M. J. J. Harrison (Pennsylvania):—The report of the Yards and Terminals Committee appears in Bulletin 361 commencing on page 419.

At this time your Committee recommends the revision of two sections of the Manual and the withdrawal of a third section thereof, and submits as information reports covering Grain Elevator Storage Yards and Plant Tracks, Hump Yards, Scales Used in Railway Service, Expediting of Freight Car Movements through Yards, and a Bibliography.

On the subject of Coordination of Facilities at Rail-and-Water Terminals, your Committee reports active work under way but not advanced sufficiently for the preparation of a report.

At this time your Committee wishes to acknowledge receipt of letters commenting on its present report. Such letters have been received from a gratifyingly large number of members of the Association, and your Committee wishes to thank these members for their interest. Their several comments will have the careful consideration of this Committee.

The first assignment is Revision of Manual. Under this heading your Committee first invites your attention to pages 420 and 421 of the report where revision of six paragraphs of the section of the Manual covering freight yards is recommended, namely paragraphs (1), (5), (23), (25), (28) and (50). The present and proposed forms of these items are shown in the report. Your Committee recommends, and I move the adoption of the six paragraphs named in their proposed form in lieu of the present form.

(The motion was put to a vote and carried.)

Chairman M. J. J. Harrison:—Your Committee now invites your attention to pages 421 to 434 of its report where a general revision of the section of the Manual entitled Rules for the Location, Maintenance, Operation and Testing of Railway Track Scales is recommended.

By way of explanation, your Committee has been working for some few years with the aim of getting this material in acceptable form. Furthermore, at the present time the Traffic Division of the American Railway Association, through its Committee on the Weighing and Inspection of Freight Traffic, is most anxious to reissue in pamphlet form these rules, for which, in the present scheme of organization, it must depend on this Association. To enable the Traffic Division to reissue its pamphlet, your Committee has made a critical review of this entire section of the Manual and recommends for adoption the material shown under the heading Proposed Form in this portion of its report.

In Section I—Location, certain minor changes are proposed as shown.

In Section II—Maintenance and Operation, the same comment applies.

In Section III—Testing, a revision of the first paragraph and the deletion of present paragraphs 2 and 5 are proposed, the material contained therein being included elsewhere in the proposed form.

In Section IV—Equipment for Testing, certain minor changes are proposed as shown in the report. In addition to the form shown on page 426, and prompted by one of the letters of comment recently received by the Committee, your Committee proposes to insert in the seventh line of Paragraph 1, near the top of the page under Proposed Form, and following the word "cars", in parentheses "See Item 2-b Section 6 hereof," making that entire sentence read: "The working standards used in compartment type test weight cars (see Item 2-b, Section 6 hereof) should be rectangular and of such design as to facilitate stacking."

Former Section V was withdrawn from the Manual by action of the 1931 convention. The material here proposed as a new Section V—Definition of a Standard Test of a Railway Track Scale, was presented to the 1933 convention as information. During the past year your Committee has reviewed this material and has concluded to recommend certain revisions in paragraphs 6 and 8 thereof. These two paragraphs are shown on pages 426, 427 and 428 of the report, the columns headed Present Form being the material submitted as information a year ago. Paragraphs 1, 2, 3, 4, 5 and 7 of this section are shown on pages 433 and 434 of the report, and no change from the form in which they were presented as information is now proposed by your Committee.

There is a typographical error, the fault of which lies with your Committee Chairman, in the last line on page 426. The first full word in that line under Proposed Form reads now "disconnected" and it should read "connected."

Section VI—Specifications for Railway Track Scale Test Weight Cars. This section was adopted as Manual material by the 1933 convention and is included here by reference only. No revision of this section is now proposed by your Committee.

In lieu of old Section VII—Test Weight Cars, an entirely new Section VII—Rules for Maintenance and Transportation of Track Scale Test Weight Cars is proposed. This new material was submitted as information at the 1933 convention, and no revision of that form is now proposed by your Committee.

Section VIII is proposed to stand with the present wording, with the addition of a number identifying it as a section of these rules.

Your Committee recommends, and I move, the adoption of the proposed form of this section of the Manual to replace existing Manual material as indicated in the report and with the corrections I have just mentioned.

The President:—You have heard the motion. It is now before you for discussion. This is rather a lengthy report and we should have some discussion upon it. It is a very important one. I will ask the Chairman to offer each section of it by title to the convention for discussion and revision or amendments to the subject-matter.

Chairman M. J. J. Harrison:—Rules for the Location, Maintenance, Operation and Testing of Railway Track Scales—

Section I—Location:

1. General Conditions.
2. Alinement of Live and Dead Rails.
3. Gradients for Motion Weighing.
4. Runoff Gradient for Spot Weighing.

Section II—Maintenance and Operation:

1. Numbering Scales.
2. Scale Shop.
3. Cleaning.
4. Rust Preventive for Pivot and Bearing Steels.
5. Removal of Ice.
6. Standing of Equipment Prohibited.
7. Restriction to Use of Live Rails.
8. Cars Restricted to Live Rails or Dead Rails Only.
9. Use of Sand and Injector.
10. Weigh-beam.
11. Stopping Cars on Scales.
12. Automatic Weighing and Recording.
13. Locking Scale Houses.
14. Inspection by Weighmaster.
15. Painting.

Section III—Testing:

1. Test Frequency.
2. Weekly Tests.
3. Daily Tests.

Section IV—Equipment for Testing:

1. Standard of Mass.
2. Even Arm Balance and Master Scale.

Section V—Definition of a Standard Test of a Railway Track Scale, and here we turn for continuity to page 433:

1. Test Equipment.
2. Test Car Positions.
3. Zero Load Balance.
4. Sensibility-Reciprocal.
5. Classification of Tests.
6. Scales with Automatic Weight Recording Attachments.
7. Test Record.
8. Tolerances.

Section VI—Specifications for Railway Track Scale Test Weight Cars. This is material which now appears in Bulletin 356 and is included here only by reference.

Section VII—Rules for Maintenance and Transportation of Track Scale Test Weight Cars:

1. Classification.
2. Weight Control.
3. Transportation.

Section VIII—Disposition of Obsolete Track Scales.

The President:—I should like to have some discussion on this very valuable report.

Chairman M. J. J. Harrison:—I might say that the Committee has received in the last two or three days rather extended written discussions from three members of the Association covering various points included here. As already stated, the Committee is very appreciative of these comments. They will be taken under careful advisement by the Committee.

The President:—Are you ready for the question? The question is on the adoption and printing in the Manual of these specifications as revised. All those in favor will signify by saying "aye"; contrary. It is carried and so ordered.

Chairman M. J. J. Harrison:—The matter of withdrawal of the section of the Manual entitled "Specifications for the Manufacture and Installation of Motor Truck, Built-in, Self-Contained and Portable Scales for Railway Service" will be handled as a part of the Committee's report on its assignment No. 5, Scales Used in Railway Service.

Our assignment No. 2 is Grain Elevator Storage Yards and Plant Tracks. The report will be presented by Mr. W. H. Giles, Chairman of the Sub-Committee.

Mr. W. H. Giles (Missouri Pacific):—The report of Sub-Committee (2), Grain Elevator Storage Yards and Plant Tracks, will be found in Bulletin 361, page 434. The information contained in the report has been assembled after study of replies to questionnaires sent to various railroads. The three general types of elevator plants served by the railroads are mentioned and a brief description of the plant tracks included.

The characteristics of plants as reported are shown in the statement on pages 438 and 439. An example of a rail to rail plant is shown in Fig. 1 at page 436, and Fig. 2 on page 440 shows a rail to water plant.

It is recommended that the report be received as information.

The President:—Is there any objection to receiving this report as information? If not, it will be so received.

Chairman M. J. J. Harrison:—Assignment (3) is Hump Yards. The report will be presented by Mr. E. M. Hastings, Chairman of the Sub-Committee.

Mr. E. M. Hastings (Richmond, Fredericksburg & Potomac):—You will find the report of this Sub-Committee on page 441 of Bulletin 361.

This report is a further discussion of the graphic method to be used in designing gradients in connection with the application of car retarders to hump yard operation, particularly concerning application under Graphic Method "B", a discussion of which was presented to the 1933 convention. The report which is now presented completes the discussion of the graphic method of design. It is intended only to describe the methods so that anyone desiring to use these graphic methods may have full information as to their application. There are no conclusions to be drawn. The discussion in the report is presented for the information of the Association.

The President:—They will be accepted as information. If anyone wishes to discuss these reports that are to be accepted as information, we will be glad to have them rise and take part in the proceedings.

Chairman M. J. J. Harrison:—Assignment (5) is Scales Used in Railway Service. The report on this subject will be presented by Mr. H. M. Roeser, Chairman of the Sub-Committee.

Mr. H. M. Roeser (Howe Scale Company):—This report has to do with Appendix D on page 447, Bulletin 361, and has for its purpose revision of Specifications for the Manufacture and Installation of Motor Truck, Built-in, Self-Contained and Portable Scales for Railway Service now in the Manual beginning on page 1034. The public has shown a tendency to generally depend on these specifications, and thus they

have come to have the standing of a monument of professional merit of the Association in fixing standards not only for the purpose of the transportation industry but for others.

To add security to that phase of the activity, as well as to add clarifying and completing features the specifications have always lacked, the assignment became desirable at this time.

Completing the assignment during the past year was found impossible. However, interest in the developments had become such that, by the time of the fall meeting, the Committee decided to recommend deletion from the Manual of the specifications, and publication of the work so far completed in the Proceedings as information. Subsequently, opportunity was found to forge a bit further ahead, but at that time Bulletin 361 had been printed. We then concluded upon making the complete action to date available by proposing the supplemental report just now distributed among you.

We will have to apologize for the ragged form in which this report is presented. It represents, first, our desire to get on record with the progress to date, and, second, it reflects the impossibility of completing the assignment within the past year.

I shall not dilate upon it except in so far as that required in the action now proposed. I want to offer two motions, the first of which is to move deletion from the Manual the subject-matter beginning on page 1034 under the caption "Specifications for the Manufacture and Installation of Motor Truck, Built-in, Self-Contained and Portable Scales for Railway Service."

The President:—It has been moved and seconded that the subject-matter on page 1034 of the Manual, Specifications for the Manufacture and Installation of Motor Truck, Built-in, Self-Contained and Portable Scales for Railway Service be deleted from the Manual. Is there any discussion? All those in favor say "aye"; contrary. It is carried and so ordered.

Mr. H. M. Roeser:—The action to be proposed is a little unusual, but at the direction of the Committee I move the publication as information of the work thus far completed on the assignment of revising the Specifications for Motor Truck, Built-in, Self-Contained and Portable Scales for Railway Service, the same to serve ad interim the purpose of the material on the same subject deleted from the Manual by the action taken on the last motion.

The President:—You have heard the motion to print in the Proceedings. All the reports that are submitted as information are printed in the Proceedings. The Committee, I take it, wants to add a little emphasis to this report and call the attention of the members to the fact that it is in shape to be used but that they are not quite ready to recommend it for the Manual. Is that correct?

Mr. H. M. Roeser:—Yes.

The President:—Is there any discussion on this report? All those in favor say "aye"; contrary. It is carried.

Chairman M. J. J. Harrison:—On assignment (6) Bibliography on Subjects Pertaining to Yards and Terminals, I will ask Mr. Tratman, Chairman of the Sub-Committee, to present this report. The Committee again desires to record its appreciation of Mr. Tratman's efforts in compiling this Bibliography, which we feel was quite worth while.

Mr. E. E. R. Tratman (Civil Engineer):—As to the Bibliography, there is not much to say. The Committee has got together a lot of information which it hopes may be of use. There is one point to which I might call attention. In the great variety of subjects included in the Bibliography, besides the list of individual yards and passenger terminals, you will find such items as city planning, valuation, switching charges, and

so forth. Those, of course, have more to do with operation, but the work of this Association includes both engineering work and operating work. They illustrate also the variety of subjects involved in yard and terminal problems.

Another point is as to the quantity. Owing to my leaving for Europe in July, this printed list only comes down to last June. I am now working on the remainder of it, and I hope that the list printed in the next report of the Committee will be very much longer than this.

There is just one other point. You will notice some items as to the container system. In England I was much surprised at the great extent of the use of containers, but their use is very much simpler in that country because 90 per cent, possibly 95 per cent of their cars are only of eight or ten tons capacity. Therefore, the single container makes a single carload, while here we usually have to put six or eight or more containers on a car to make a good load. Finally, I can only say we hope that members of the Association will find some use for these bibliographic lists.

The President:—This Bibliography will be printed in the Proceedings.

Chairman M. J. J. Harrison:—Assignment (7) Expediting of Freight Car Movements through Yards. The report on this subject will be presented by Mr. W. F. Cummings, Chairman of the Sub-Committee.

Mr. W. F. Cummings (Boston & Maine):—The report of Sub-Committee (7) the Expediting of Freight Car Movements Through Yards, is shown on pages 466 to 472, both inclusive, of Bulletin 361. The report of the Committee this year has been confined to statements to show the importance of the subject and a listing of some of the facilities which will help in its solution.

The Committee intends, if the assignment is continued, to study the more specific phases of the subject. The report is offered as information with a request that the subject be continued.

The President:—Is there any discussion on this report? The Committee would like to have expressions of opinion on all these reports that are offered as information. The report will be received as information and printed in the Proceedings.

Chairman M. J. J. Harrison:—If I may supplement what you said, the Committee would be very appreciative of any written discussions that any of the members might have to offer.

This concludes the report of the Committee on Yards and Terminals.

The President:—The information presented by this Committee is timely and valuable, and we will now excuse them with the thanks of the Association (Applause).

Mr. C. E. Smith (Vice-President, New York, New Haven & Hartford—by letter):—This Committee has had a long and creditable career, which is being continued by its present personnel. Much good work has been done. The latest report is one of the best. Every railroad man should appreciate the opportunity of having such information prepared for him by the Committee.

Mr. Charles H. Blackman (Principal Assistant Engineer, Louisville & Nashville—by letter):—I have gone over this report very carefully, and take this opportunity to congratulate the Committee on having done some good work.

There are, of course, some minor changes and corrections that the Committee itself will no doubt make after giving it further consideration.

For instance, in the proposed revision of specified items covering freight yards, paragraph 5-(d) could, I think, be omitted entirely. In paragraph 28, three words could be omitted, making a part of the sentence read—"move directly to the departure tracks".

Under the Rules for Location of Track Scales, I am not at all in accord with the statement in Section 1, paragraph 1-(a). The presence of the scale in a much-used track does add to the maintenance, inspection and testing troubles, but I do not see that it is particularly dangerous to trainmen.

In the old form of this paragraph, the 60 per cent requirement of cars to be weighed in proportion to total number of cars handled applied only to flat yards, but in the proposed revision you are making this applicable to all yards. In a hump yard, I think the scale should be on the hump if even as much as 20 per cent of the cars are to be weighed, for otherwise these cars would need to be dropped into a special classification track for weigh cars and then rehumped for classification after weighing. There are no points on our line, other than assembling yards in the mine districts, where anything like 60 per cent of the cars passing through the yard need to be weighed.

With reference to paragraph 1-(c) of Section 1, I beg to say that we have points where the scale is located on an inner body track, tracks being spaced on wide centers to permit such installation. I agree that it is not economical.

The specifications given in Appendix D would seem from the wording to have been prepared by or in co-operation with some manufacturers committee. I would suggest that such paragraphs be eliminated before the specifications be adopted for publication in our Manual.

As a matter of fact, the importance of scales of this type would not justify the average railroad in making the inspection necessary to see that the scales were manufactured in compliance with specifications of this type, and, in fact, if we undertook to purchase to these specifications, we would simply ask the manufacturer to state whether the scales did or did not comply with these specifications.

In Appendix F, I note that the Sub-Committee realizes the importance of its subject, although its report for this year simply consists of a statement of the problem. The problem is one on which the future existence of the railroads depends, and it would seem that it might be given jointly to the Yards and Terminals Committee and the Committee on Economics of Railway Operation, and if these committees can offer any constructive suggestions to our operating and managing officers they will have performed a service of enormous value to the railroads.

Mr. Benj. Elkind (Erie Railroad—by letter):—I have reviewed this report and have no comments to make, other than to suggest that on page 421, under paragraph 'c' in connection with length of a scale track which is also a body track, the scale track should extend the length from the scale in both directions to clear the longest cut of cars to be weighed instead of "it should be twice as long as the longest cut of cars to be weighed".

Mr. H. M. Stout (Northern Pacific—by letter):—In going over this report and discussing portions, it has been observed the tolerances which are included in the proposed revision of the Manual under the title, "Proposed Revision of Rules for the Location, Maintenance, Operation and Testing of Railway Track Scales," are greater in several rather important instances than are permitted in our practice.

Of course, you are acquainted with the "Specifications for the Manufacture and Installation of Railroad Track Scales", approved by the Minnesota Railroad and Warehouse Commission, effective in the State of Minnesota since June 1, 1920, which were prepared, except for some additions, by a committee appointed by R. H. Aishton, then Northwestern Regional Director of Railroads of the Federal Administration of Railroads, representing (1) the American Railroad Association, (2) the American Railway Engineering Association, (3) the United States Bureau of Standards, (4) the Railroad and Warehouse Commission of Minnesota, (5) the National Scale Men's Association,

and (6) the Scale Manufacturers' Association. The requirements of these specifications are more exacting than those of most States having established rules governing these matters. So far as is known, our scales are all maintained, throughout the seven Northwestern States which our lines serve, within the tolerances of the Minnesota specifications, although in some of them the supervision and requirements of the State authority make minimum demands upon the railroads as to the condition of scales.

Comparing our practice with the proposed revised specifications for the Manual of your report, the following are noted:

Section III—Testing; paragraph 5: A maximum error of two pounds per thousand is allowed, whereas our requirements permit but one pound per thousand.

Section V—Definition of a Standard Test of a Railway Track Scale; 8—Tolerances.—(1) Maintenance Tolerances, paragraphs (a), (b) and (c): In each case, the tolerance is 2/10 of 1 per cent, or 2 lb. per 1000 lb. of test load, whereas our requirements are 1/10 of 1 per cent, or 1 lb. per 1000 lb. of test load.

Section VII—Rules for Maintenance and Transportation of Track Scale Test Weight Cars; (2) Weight Control.—(c) Frequency of Verification Recommended.—(3) Verification of Terminal Test Weight Cars: Instead of the minimum of twice yearly of your specifications, our requirements are four times per year, or 2500 miles.

Although not specifically stated in the Minnesota specifications, the inspectors for the M.R.R.&W.C. recommend the live rail be the straight rail in any track scale installation, and the dead rail be the offset rail. This is to eliminate the pull of heavily loaded and stiff cars while on the scale. This is the reverse of the Committee's specification, Section I, paragraph 2—Position of Live and Dead Rail.

The Minnesota Railroad and Warehouse Commission have not prepared any specifications for the construction, installation and maintenance of scales for motor trucks and other uses in railway service, nor have other of our States provided specific regulations for them, comparable with the specifications submitted in Appendix D of your Committee's report.

I am of the opinion the discussion of the Committee on the three subjects under study as given in appendices

(B) Grain Elevator Storage Yards and Plant Tracks,

(C) Hump Yards,

(E) Bibliography of Subjects, pertaining to Yards and Terminals appearing in Current Periodicals, constitute valuable contributions to the study of the modern railway yard, and Appendix F—The Expediting of Freight Car Movements through Yards—is a commendable approach to and statement of the problem.

The Federal Coordinator of Transportation, in his first and preliminary report to the Interstate Commerce Commission, and through them to the President and the Congress, has made repeated references to the operating costs of railroad terminals. I apprehend the Committee may find much of interest in the studies and investigations which have been made and are being carried on by the Coordinator and research under him and which, he complains, although worthy of publication, lack of funds will not permit. He has said, however, the information gathered has been assembled in convenient form for reference purposes.

Mr. B. T. Anderson (Union Switch and Signal Company—by letter):—I was particularly interested in this report, and especially in those sections of it relative to hump yards and expediting the freight car movements through yards, as these sections refer particularly to car retarders and signaling, in which I am very much interested.

The Committee is presenting a well-prepared report, and they are to be congratulated on the manner in which the subject has been covered.

I have no exceptions to take to this report, and feel that it should be presented to the Association as prepared.

Mr. Hadley Baldwin (Cleveland, Cincinnati, Chicago & St. Louis—by letter):—I have read through the report of the Yards and Terminals Committee, appearing in Bulletin 361, with much interest. It is a fine report, such as manifestly requires much valuable time and exhaustive analysis.

I may refer particularly to the recommendations of Sub-Committees 1 and 5 as dealing with the general subject of scales. Having myself participated rather strenuously, though enjoyably, in what perhaps may be characterized as the Association's original thoroughgoing treatment of this subject at the hands of the Yards and Terminals Committee, I have maintained a rather special interest in the continued efforts of the Committee which have refined and expanded the significance of what was in the beginning brought forth.

More for the sake of feeling for the moment as if I were again a member of the old Committee than because of any probable necessity, and at the risk of showing that my knife-edges have grown a little dull or rusty, I am going modestly to append a few comments on the proposed revision of "Rules for the Location, Maintenance, Operation and Testing of Railway Track Scales," as follows:

Section I—Location. 1-(a) The expression "except in special cases" seems to make it necessary to consider a hump scale a special case, which might not be generally understood. 1-(e) It would be better, I think, to insert "otherwise" after the word "when", and I think I would go so far as to substitute the word "might" for the word "would" in the last line. 2. The new definition is less inclusive than the old.

Section II—10. The word "maximal" is OK, but was a new one to me.

Section IV—1. The nominal value of working standards is not designated, but apparently should be, as basis for the tolerance prescribed.

Section V—6. Apparently the word "connected" should be substituted for the word "disconnected" at end of first sentence.

3-(a) It would appear that the word "more" should be substituted for the word "less" at the end of the fifth line.

In view of my present remote contact, I cannot recruit the temerity to undertake any exhaustive estimate of the technique of the reports in question. It required maximal effort for me to keep up with tolerance when I was in the heat of conflicting opinions that our earlier wrestling with the major and microscopic issues of scale etiquette seemed properly to engender.

I'll bet, though, that the boys' conclusions are all right, or anyway that they are better than ever.

Col. F. W. Green (St. Louis–Southwestern—by letter):—A reading of this report impresses me with the fact that the Committee's proposals in a number of instances will result in changes that will be beneficial to the railways. The report also elaborates and amplifies the present information in other instances.

The Committee is to be complimented on its work. It accomplished what it endeavored to do, which was to produce a worth-while report.

Mr. S. S. Roberts (Assistant Director of Finance, I.C.C.—by letter):—I regret that business at the office and personal business that required immediate attention have prevented my reading the entire report of the Committee. I have, however, read in a cursory manner that part of its report concerning the selection of gradients for retarder operated hump yards.

Since it is probable that no two cars will roll exactly alike, and that the same car will roll differently under different conditions of weather and of lading, no rule or for-

mula will give reliable results under all conditions. I have found that by the use of velocity-heads and car resistance there will be obtained as reliable indications of speed and gradients necessary to produce these speeds as by the use of any other method.

In the design of hump yards, I have endeavored to obtain sufficient fall from the top of the hump to the tail end of the yard so that a slow rolling car would roll to clearance at the tail end of the yard, and I depended on the car riders to so control the speed of easier rolling cars by the use of hand brakes, that such cars would roll to coupling without damage to the car or contents. The introduction of car retarders transfers the responsibility for the speed of the easy rolling cars from the car riders to the tower man who operates the retarders. Although the introduction of car retarders requires a different track layout and arrangement of ladders at the head end of the yard, the outstanding difference between the hump yard operated by car riders and that operated by retarders is that mentioned above.

In hump yard designs that I have made in the past I held the gradients of the track, or the two tracks, through the center of the yard and the gradients of the two outside tracks of the yard as controlling the gradients of the intervening tracks. It is not clear to me why the introduction of car retarders should cause a departure from the above procedure.

I here call your attention to my letters of February 9 and February 16, 1933, to Mr. E. M. Hastings, Chairman, Sub-Committee 6, Hump Yards, Committee XIV, together with the photostats of suggested head end plan for retarder operated classification yard which accompanied these letters. I have not been advised by the Committee whether it found any merit in the plan I suggested. My past experience leads me to believe, until I am otherwise convinced by facts that are not now within my knowledge, that the plans I suggested have merit. Under these plans the gradients for the two tracks through the center of the yard and the gradients for the two tracks on the outside of the yard should be controlling. The body tracks of the yard should have substantially the same gradients. The elevations of each succeeding body track from the center of the yard to the outside track should be proportionately lower than the elevation of the track through the center. The surface between the tracks between the center and the outside tracks at the head end of the yard on which rests the switch leads and the car retarders may be a warped surface, but the surface of the entire yard will generally fall from the hump toward the tail end of the yard and crosswise from the center tracks to the outside tracks, except that toward the tail end of the yard there should be generally a light rising gradient to bring the cars to rest at or before they reach the clearance point.

In attacking the problem of determination of gradients for such a yard, it seems to me now that I should design gradients from the top of the hump along the two center tracks of the yard and from the top of the hump along the two outside tracks of the yard so that the slowest rolling car would roll to clearance with all of the retarders open, that is, inactive, and then select the proper number of retarders located in the most effective places to so control the speed of the easier rolling cars so that the easiest rolling car should come to rest at or before reaching the clearance point at the tail end of the yard. The gradients of the tracks intermediate between the center tracks and the outside tracks should automatically take care of themselves.

In my opinion, the time spacing of cars in the car rider hump yard is controlled principally by the engineer of the hump engine, the man who cuts the cars at the hump, and the car riders. In the retarder operated yard the retarders are substituted for the car riders. In considering speeds, no slow rolling car should attain a speed so great as to cause danger of derailment on the switch leads or on the curves when all of the re-

tarders are open, or inoperative, and no easy rolling car should attain a speed so great that it could not be brought to rest by a retarder without damage to the car or contents. Thus, in designing the gradients at the head end of the yard, consideration must be given to the capacity of the car retarders and to the frequency of their insertion as determined by their capacity.

I have not the time nor the facilities, for drawing the head end plan I suggested, using a number 8, 9, or 10 frog. I should think it would be worth-while for the Committee to either make such a drawing or to compute the horizontal distances that would be required for such a yard with a frog of practical number from which it should be possible to determine whether or not gradients of practical use could be applied to it.

In my opinion, the plan I suggested in February, 1933, lends itself to a practicable development of gradients both for speed and for drainage purposes.

Mr. F. L. C. Bond (Canadian National Railways—by letter):—In reviewing the various reports as submitted by the Sub-Committee, I find that this Committee has been assigned subjects which are of great interest to the railways, especially at this time with present business conditions and trucking competition, making it essential that our freight traffic be moved as speedily and economically as possible. The report on the Expediting of Freight Car Movements Through Yards is particularly important and instructive and undoubtedly the study of this subject should be continued as its solution will solve one of our major transportation problems.

The report clearly indicates that a great deal of study and effort has been given by the members of the Committee and they certainly should be complimented on their excellent work.

DISCUSSION ON RULES AND ORGANIZATION

(For Report, see pp. 521–528)

Mr. E. H. Barnhart (Baltimore & Ohio):—You will find the report of Committee XII in Bulletin 361 beginning on page 521.

For several years this Committee has collaborated with Committee XI—Records and Accounts in the preparation of bridge inspection forms.

In order to bring the subject-matter now in the Manual covering bridge inspection in conformity with the revised forms which Committee XI will recommend for adoption, a revision of several paragraphs is necessary. The report of the Sub-Committee on Revision of the Manual will be presented by Mr. Coons, Chairman of the Sub-Committee.

Mr. P. D. Coons (Burlington):—The revision just referred to will be found on page 522 of Bulletin 361. The recommended changes cover three numbered rules, 1353 and 1359, and the elimination of 1415.

I move the recommended changes be approved.

The President:—It is moved and seconded that these rules be revised as shown in the proposed form on page 522 of the Bulletin. The question is now before you for discussion. All those in favor of this motion will signify by saying "aye"; contrary. It is carried.

Chairman E. H. Barnhart:—Rules for Maintenance of Bridges—Masonry have been before the Association for the past two years. Last year these rules were referred back to the Committee for certain revisions. The revisions have been made and the report of this Sub-Committee will now be presented by Mr. Griggs, the Chairman of the Sub-Committee.

Mr. A. B. Griggs (Santa Fe):—The report of the Sub-Committee on Maintenance of Bridges appears in Bulletin 361, page 522 under Appendix B. The report consists of Rules 1150 to 1164, inclusive. The Committee's report has been under study for about two years, and the rules here submitted are the result after giving consideration to all of the suggestions offered to the report which was before the convention last year.

The rules have the approval of Committee VIII—Masonry and of Committee XV—Iron and Steel Structures. I move that Rules 1150 to 1164, inclusive, be adopted for printing in the Manual as recommended practice.

The President:—The motion is before you to adopt Rules 1150 to 1164, inclusive, as recommended practice and for printing in the Manual. The matter is now open for discussion. Are there any suggested revisions? All those in favor of the motion will signify by saying "aye"; contrary. It is carried and so ordered.

Chairman E. H. Barnhart:—For the past five years this Committee has had assigned to it the preparation of rules covering maintenance of telegraph and telephone lines and appurtenances. You will find in Appendix C the rules which have been proposed. These rules have been prepared by a Sub-Committee of the T&T Section and are submitted as particularly applying to Maintenance of Way employees. The Committee requests that members of the Association who are interested in this phase of maintenance of way work, carefully go over these rules and submit to the Committee any criticism or suggestions.

The Committee offers the rules in Appendix C as information.

The President:—Is there any discussion on this subject? The matter will be received as information and printed in the Proceedings.

Chairman E. H. Barnhart:—Last year the Committee presented as information appropriate titles for the position known as Assistant Engineer, in all departments. Mr. Brooke and his Sub-Committee have spent considerable time and study in obtaining this data. Unfortunately, Mr. Brooke is unable to be present this morning, on account of illness, to present his report. The report of the Sub-Committee will therefore be presented by Mr. Warden, the Vice-Chairman of the Committee.

Mr. R. E. Warden (Missouri Pacific):—The Committee submitted as information last year appropriate titles for Assistant Engineers, in all departments. This information was collected after considerable investigation and study, and the membership was appealed to for criticisms and suggestions. Since the submission of this information, no criticism or suggestions have been received. The Committee, therefore, submits, in Appendix D, these titles for approval and printing in the Manual.

These titles are found on page 526. I move that they be accepted and printed in the Manual.

The President:—It has been moved and seconded that these titles as shown on pages 526 and 527 of the Bulletin be approved and printed in the Manual. Is there any discussion on these titles? All those in favor please say "aye"; contrary. It is carried and so ordered.

Chairman E. H. Barnhart:—The report of Sub-Committee (4), Rules for Fire Prevention as Applying to Maintenance of Way Department, will be presented by Mr. Hayes, the Chairman of the Sub-Committee.

Mr. H. C. Hayes (Illinois Central):—The subject assigned to Sub-Committee (4), Rules for Fire Prevention as Applying to Maintenance of Way Department, has been before this Committee for five years. These rules as now proposed are to be found on pages 527 and 528 of Bulletin 361. They cover the divisional supervisory officers only and are not to be considered as covering the whole subject of fire prevention.

These rules presented are the result of a questionnaire and represent the general practice of the majority of the railroads represented in this Association. They were presented last year as information, since which time they have been revised and rearranged in compliance with criticisms and suggestions received at the 1933 convention and subsequent letters. They have been approved by the National Board of Fire Underwriters and the Railway Fire Protection Association.

I move that the rules as offered in Appendix E be approved for printing in the Manual.

The President:—The question before you is the adoption of the rules printed on pages 427 and 428 and the printing of them in the Manual. I am going to ask the Chairman to present each article for discussion and amendment, giving an opportunity for discussion after the reading of each one.

Mr. H. C. Hayes:—Under General Rules: "33. Employees must give full cooperation to fire prevention measures and be familiar with location and use of nearest fire alarms.

"Division Engineers: 302. They must see that employees under their jurisdiction are properly instructed in fire prevention rules, alert in decreasing fire hazards and exacting in the maintenance and operation of fire fighting apparatus. When locating buildings and structures, they will see that attention is given fire prevention.

"Supervisors of Track: 316. They must give particular attention to fire hazards from adjoining property and from structures erected on railway property by lessees.

"317. They must see that those under their supervision do not obstruct fire roads, fire hydrants and hose houses.

"318. They must see that no lumber, ties, piling or other inflammable materials are piled in close proximity to any important building and that automobiles or trucks are not parked in a manner which constitutes a fire hazard.

"319. They must know that their foremen understand and observe fire prevention rules.

"Supervisors of Bridges and Buildings:

"374. They must give particular attention to fire hazards where the risk is extreme, such as oil houses, paint shops, wood coal chutes, and cotton platforms.

"375. They must make proper reports to superiors of any unguarded fire hazards.

"376. They must see that those under their supervision do not obstruct fire escapes and exit passages thereto, fire doors, hose reels, fire hydrants, fire roads, and hose houses.

"377. They must see that all sprinkler systems and fire fighting apparatus under their jurisdiction are maintained in accordance with the National Fire Underwriters Code.

"378. They must arrange through their superior officers for the proper cooperation of all municipal fire departments.

"379. They must make recommendations for fire stops when necessary, and for the removal of any fire hazards.

"379-A. They must see that inflammable materials are stored so as to confine any fire to the place of origin.

"379-B. They must know that their foremen understand and observe fire prevention rules.

"Supervisors of Water Service: 423. They must know that fire pumps and fire lines under their jurisdiction are in proper working condition, and that fire hydrants and hose are always ready for instant use.

"424. They must call attention to points where connections might be made to municipal fire mains.

"425. They must know that their foremen understand and observe fire prevention rules."

The President:—Is there any discussion on these rules? If not, all those in favor of the motion to adopt them as recommended practice and for printing in the Manual will say "aye"; contrary. It is carried and so ordered.

This Committee has done a very valuable work this year, and we will now dismiss them with the thanks of the Association (Applause).

DISCUSSION ON RECORDS AND ACCOUNTS

(For Report, see pp. 579–620)

Mr. C. C. Haire (Illinois Central):—The report of the Committee is the first one in Bulletin 362, page 579. There are fourteen assignments that have been given to us to handle during the year. Reports for eleven of the subjects are included in the Bulletin, and progress is reported on three.

Our first subject under Group A—Miscellaneous, Revision of Manual (Appendix A) will be presented by Mr. Butler in the absence of Mr. Smith, the Chairman of the Sub-Committee.

Mr. E. S. Butler (Kansas City Southern):—The report of this Sub-Committee will be found on page 580 in Bulletin 362. It has to do with the revision of the Manual, and the Committee recommends the adoption of these changes. Should they be read?

The President:—Yes. I will be glad to have you read the proposed form.

Mr. E. S. Butler:—The present form is found on pages 726 and 727, paragraphs 6 and 7, of the Manual. It has to do with Equipment Completion Report, Form 1118, and the recommendation is that that be omitted from the Manual.

The next is Labor and General Forms, Time Roll, Form 1119. There is a change proposed in that. The proposed form is: "Carriers are constantly striving to get the maximum worth of the maintenance dollar. They should be able to show that their expenses are efficiently and economically handled as a matter of sound business practice."

I move the adoption of these changes in the Manual.

The President:—It has been moved and seconded that Specifications for Form 1118 be omitted, and that Form 1119 be revised. Is there any discussion on this subject? If not, all those in favor will say "aye"; contrary. It is carried and so ordered.

Chairman C. C. Haire:—I might say, in connection with your statement made this morning, that it is the intention of the Committee under this assignment which is given us annually, to make a comprehensive study of all its material to develop a program so that when and if necessary, the entire section of the Manual devoted to Committee XI can be revised concurrently with the change in practice that may be brought about by the issuance of the new classification of accounts, depreciation order and a modified valuation procedure. We are attempting to establish this objective and work out a more modernized practice for our section of the Manual.

The next assignment given to the Committee is the one on Bibliography for subjects pertaining to records and accounts. Mr. Weymouth, Chairman of the Sub-Committee, will present the report.

Mr. A. P. Weymouth (Pennsylvania):—The report of this Sub-Committee on Bibliography is found on pages 581 to 583 of Bulletin 362. This is one of our continuing subjects, and the report has been prepared in the same manner as in previous years. We present a bibliographical review of important books and articles pertaining to records and accounts. It covers the period from November, 1932, to October, 1933, inclusive. The report is submitted as information, and the subject will be continued.

The President:—The report will be so received and printed in the Proceedings.

Chairman C. C. Haire:—Our next subject is Office and Drafting Room Practices (Appendix C). This is quite a lengthy report, and I hope it has received your attention since the Bulletin was published. It is one that is being constantly modified, and the Committee is always glad to receive any suggestions. In fact, we received quite a few from the signal people. The Chairman of the Sub-Committee, Mr. Avery, will present the report and will tell you about those changes.

Mr. D. L. Avery (Chesapeake & Ohio):—This is a report of Sub-Committee (B-1) Drawing and Drafting Room Practice. The report will be found in Bulletin 362, pages 583 to 602, inclusive.

The Committee devoted most of its time during the year to preparing a pamphlet covering electrical and signal symbols. At the request of Committee X—Signals and Interlocking and Committee XVIII—Electricity, it was decided to discontinue work pertaining to their symbols.

Last year's report of the Committee has been revised to include constructive suggestions and additions offered during the year.

It is recommended that the symbols shown on page 589 under Track Fixtures and the line of index referring to Track Fixtures on pages 584 and 585 be omitted from this report tentatively. The reason for that is this: It is the intention of the Committee to collaborate further with the Signal Section, separating signal from track symbols.

With this omission it is recommended that the graphical symbols submitted herewith in Bulletin 362, pages 584 to 602, inclusive, be approved for publication in the Manual in the place of those shown in the 1929 Manual, pages 745 to 757, inclusive, with this exception: The title, which was omitted by the printer, Drawing and Drafting Room Practice, Graphical Symbols, should be shown at the top of page 584, the beginning of the report.

I so move.

The President:—The motion is on the adoption of these symbols as recommended practice, for printing in the Manual, with the exception of Track Fixtures.

Mr. A. R. Wilson (Pennsylvania):—On page 597, at the bottom of the sheet, the proportions for rivet heads are shown. Committee XV has as its assignment Design of Rivet Heads. This Association has a member on the committee of the American Standards Association dealing with the same subject. The subject not having been concluded by either body, I think it unwise to present at the present time in the Manual proportions for rivet heads. I would leave the words "Grip" and "Length" as the definition, omitting any reference to the proportion of the head, either for buttonhead or countersunk rivets.

Mr. D. L. Avery:—It is the intention of the report to eliminate any reference to buttonhead or countersunk rivets. It was submitted in this form at the suggestion of Mr. Lang of Committee XV—Iron and Steel Structures.

Mr. J. C. Irwin (Boston & Albany):—I endorse Mr. Wilson's opinion in regard to stating any dimensions that might have an effect on the design of rivets. I see no objection to putting in a symbol which shows the manner in which they shall be indicated. Mr. Wilson is quite right in regard to the progressive work being done by the committee of the American Standards Association. It would not be the function of this Committee to have any influence on the design of rivets.

Mr. H. M. Stout (Northern Pacific):—It seems to me it would be appropriate for the Chairman of the Committee or the Chairman of the Sub-Committee at this point in the proceedings to indicate what contact or collaboration they have had with the American Standards Association. Some years ago the American Engineering Standards Committee, the former name of the A.S.A., had a committee working along this same line. The Association ought to know whether there is possible conflict between the two associations.

Mr. D. L. Avery:—This work is being prepared for the A.R.E.A. and also the A.S.A. These symbols will be submitted to the A.S.A. as recommended railroad practice if they are adopted at this convention, of course.

Mr. J. C. Irwin:—I think I might explain further that we have perfect collaboration on the question of symbols. The American Standards Association, of course, has committees on symbols, but Mr. Avery is our representative of the American Railway Association, Engineering Division. In addition to that we have representatives from the Signal Section and the Electrical Section on that same Committee on Symbols of the American Standards Association.

I think this is a progressive step, but what is produced here undoubtedly will have its influence on what action is taken in the American Standards Association committees. I see no objection to our approving what is presented by Mr. Avery, and I have no doubt that so far as the railway symbols are concerned that will be what will be adopted by the American Standards Association committee. Is that the question?

Mr. H. M. Stout:—Yes.

Mr. J. C. Irwin:—I think you have perfect coordination.

Mr. D. L. Avery:—Is it the intention of Mr. Wilson that we eliminate the symbol covering rivets?

Mr. A. R. Wilson:—I think it desirable to retain in the report the picture of the rivet, giving the definition of the word "Grip" and "Length", and it is unwise to continue in this report any reference to the dimensions of the rivet head.

Mr. D. L. Avery:—Eliminate all reference except "Length" and "Grip"? How about D, diameter?

Mr. A. R. Wilson:—I would show diameter. That applies to both the buttonhead and countersunk rivets.

Mr. D. L. Avery:—All other features of the rivet to be eliminated except those?

Mr. A. R. Wilson:—Any information that shows the proportion of the rivet head in reference to the diameter to be eliminated.

Mr. D. L. Avery:—The Committee accepts that change and will correct its plate accordingly.

The President:—Is there any further discussion? Are you ready for the question? The question is on the adoption of these symbols as recommended practice. All those in favor say "aye"; contrary. It is carried and so ordered.

This Sub-Committee is due a large amount of credit for the large amount of work they have done on this subject, and I think they are to be congratulated on their report (Applause).

Chairman C. C. Haire:—The next subject to be presented by the Committee is Joint Facility Records under Appendix D. In the absence of Mr. Bertenshaw, Chairman of the Sub-Committee, Mr. Powell will present the report.

Mr. A. T. Powell (Grand Trunk Western):—The report of the Sub-Committee on Joint Facility Records is found on pages 603 to 609 of Bulletin 362. This outlines the appraisal methods for determining rental base, includes a form on page 605, and outlines the methods for keeping the rental base up to date. On pages 606 and 607 it includes a chart and schedule of a typical jointly used facility, setting out the ownership, maintenance and operation. These will facilitate not only the proper carrying out of contracts in maintenance and operation but also facilitate proper billing between the carriers.

On page 609 the effect of the Depreciation Order on joint facility accounting is briefly outlined. If there are no comments, the Committee offers this report as information.

The President:—Is there any discussion on this report? It will be received as information unless there is some objection thereto. It is so received.

Chairman C. C. Haire:—The next subject to be presented by the Committee is Bridge Inspection Report Forms (Appendix E). This report appears on page 610, and I will make the report for the Sub-Committee. We made progress reports for the last three or four years on this subject. The matter of collaboration has been rather difficult as there are five committees involved in the design of these forms. The Committee offers three forms on pages 611, 612 and 613, which is, I might say, a compromise midway between considerable detail and a brief form of reports. The explanatory text on page 610 shows how these forms are to be used.

The Committee recommends that Forms 1110 Rev., 1110-A and 1110-B, together with the explanatory text on page 610 be approved by this convention for inclusion in the Manual. I so move.

The President:—It has been moved and seconded to adopt as recommended practice and for inclusion in the Manual the three forms as shown on pages 611, 612 and 613. Is there any discussion on these forms? If anyone has any revisions to suggest the Committee will be glad to have you so state.

Mr. W. A. Radspinner (Chesapeake & Ohio):—There is no reference made to water barrels.

Chairman C. C. Haire:—The Committee spent considerable time on these reports and secured most of the forms that were used by the railroads throughout the country. Some of you recall that they had previously been printed in the Proceedings as information, to which there was some objection as to the great amount of detail. Then, again, we designed a series of simpler reports, practically blank. Others raised the objection that there was not enough detail. So the five committees, through their representatives, attempted to strike a medium, and the forms presented here are the result. I think you will find that there are enough blank spaces, and the forms are flexible enough to include most of the detail.

My attention is called to the fact that on the form on page 611, near the bottom, water barrels and ladders are shown as an item.

The President:—Is there any further discussion? Are you ready for the question? All those in favor of adopting these three forms as recommended practice and for printing in the Manual say "aye"; contrary. It is carried and so ordered.

Chairman C. C. Haire:—Our next group of subjects is under Maintenance of Way Reports and Records. The first assignment under this group is (1) Statistical requirements of operating, accounting and other departments with respect to maintenance of way and structures. The report is shown under Appendix F, and Mr. W. F. Cummings will present the report of the Sub-Committee.

Mr. W. F. Cummings (Boston & Maine):—The report of Sub-Committee (C-1) of Committee XI is shown on pages 614 and 615 of Bulletin 362. This Sub-Committee is progressively studying and reporting as to forms and data outlined on the Chart of Accounting and Statistical Report Procedure in Maintenance of Way Departments shown on page 278, Vol. 27 of the Proceedings of this Association.

This year the Committee presents a form to cover the Recapitulation and Distribution of Material.

I ask that the report be received as information and that the subject be continued.

The President:—Are there any remarks on this report? It will be received as information and the subject continued.

Chairman C. C. Haire:—Under this same group of subjects the Committee presents a report under Appendix G dealing with railway water service records and forms. This subject has been with us for a number of years, and each year we have brought in a series of reports, one or more. We now bring the whole matter before you for

action on the part of this convention. I will ask Mr. Teal, the Chairman of the Sub-Committee, to present the report.

Mr. D. C. Teal (Chesapeake & Ohio):—The report will be found in Bulletin 362 on page 615. It consists of a summary of work done and recommendations regarding inclusion of new and the withdrawal of obsolete material from the Manual.

The work of the Committee has been to develop an up-to-date system of Water Supply Department forms to replace ones now appearing in the Manual. Forms now in common use have been collected and classified. Forms representing each general classification have been designed and presented to the Association during the past three years.

Forms presented are as follows: Cost of water production form presented in 1931; Monthly report of water station operation form presented in 1932; Quarter monthly report of water treating plant operation presented in 1933, and Record of water station facilities presented in 1933.

It is believed that the above forms together constitute an up-to-date system of essential water supply department forms that fulfill the requirements and cover the needs of present-day water service organizations.

The Committee recommends, and I move, that these forms be published in the Manual. The Committee recommends, and I move, that obsolete Water Service Department forms be withdrawn from the Manual.

The President:—I will ask that the Chairman make separate motions. There are four or five different subjects, and I would like to have them put before the convention separately.

Mr. D. C. Teal:—I move that Form 1302-Rev., together with text relative to same, as presented on pages 523 and 524 in Vol. 32 of the 1931 Proceedings, be published in the Manual.

The President:—The question is before you for discussion. These recommendations are relative to water service, and I wish Mr. Bardwell, if he has any suggestions, would please state them.

Mr. R. C. Bardwell (Chesapeake & Ohio):—Committee XIII—Water Service and Sanitation, have gone over these forms and worked in collaboration with this Committee, and the forms that have been presented during the previous years have received the endorsement of the Association. It is the opinion of Committee XIII that it is entirely proper that the present out-of-date forms now appearing in the Manual be eliminated and replaced by these forms which bring the information into much better shape.

The President:—Are you ready for the question? All those in favor say "aye"; contrary. It is carried.

Mr. D. C. Teal:—I move that Form 1302 appearing on page 956 of the 1929 Manual be withdrawn.

The President:—Is there any discussion? All those in favor say "aye"; contrary. It is carried.

Mr. D. C. Teal:—I move that Form 1301-Rev., together with text relative to same, as presented on pages 599 and 600 in Vol. 33 of the 1932 Proceedings, be published in the Manual.

The President:—Is there any discussion? All those in favor will vote "aye"; contrary. It is carried.

Mr. D. C. Teal:—I move that Form 1301 appearing on page 955 of the 1929 Manual be withdrawn.

The President:—Is there any discussion on this motion? All those in favor will vote "aye"; contrary. It is carried.

Mr. D. C. Teal:—I move that Form 1301-A, together with text relative to same, as presented on pages 239 and 240 in Vol. 34 of the 1933 Proceedings, be published in the Manual.

The President:—Is there any discussion on this motion? All those in favor say "aye"; contrary. It is carried.

Mr. D. C. Teal:—I move that Form 1303-Rev., together with text relative to same, as presented on pages 241 and 242 in Vol. 34 of the 1933 Proceedings, be published in the Manual.

The President:—Is there any discussion? All those in favor will say "aye"; contrary. It is carried.

Mr. D. C. Teal:—I move that Form 1303 appearing on page 957 of the 1929 Manual be withdrawn.

The President:—All those in favor of this motion say "aye"; contrary. It is carried.

Chairman C. C. Haire:—The next subject comes under the general heading of Valuation. We have had with us for a long time the subject that appears under Appendix H, Methods and forms for gathering the data for keeping up to date the valuation and other records of the property of railways. A report has usually been brought in each year attempting to record the many changes taking place because of Federal regulations, particularly changes on account of Valuation Order No. 3 and its various supplements.

The report will now be presented by Mr. Leete, the Chairman of the Sub-Committee, and is shown on page 617 of Bulletin 362.

Mr. P. R. Leete (New Haven):—As Mr. Haire said, the report of this Sub-Committee (E-1) will be found on page 617 of Bulletin 362.

During the past year there has been one change of importance, and that was the amendment to the Transportation Act. In order that you may draw your own conclusions as to what effect that will have upon our work, the paragraph of the original Act and the Act as amended have been printed here in parallel columns. About the only thing that I want to say is that we think there has been a feeling abroad by those perhaps not too well informed that the elimination of recapture has virtually cut the heart out of the valuation requirements. We feel that that is not so, except as to those carriers that were actually subject to recapture and had to defend themselves before the Commission. As to other carriers, the requirements are substantially as they were before.

As this matter is so closely tied in with the Depreciation Order and the proposed revision of the classification of accounts, there is very little progress that the Committee can make in the way of any definite recommendations until those matters are settled. The report is therefore submitted as information with the expectation that the subject will be continued.

The President:—The report will be so received.

Mr. Edwin F. Wendt (Consulting Engineer):—This subject of valuation has been under discussion at every convention beginning with the year 1913. At that time you will remember there was a popular misconception regarding the capitalization of the railroads of this country. Congress passed the Valuation Act. The Committee on Records and Accounts immediately began its consideration of what should be done to assemble the necessary records which were needed as a basis of an opinion as to the question of the capitalization of the railroads.

I think every member of this Committee has had a part in the work of the collection of these fundamental records, copies of which are to be found in the offices of the railroads.

Mr. Leete referred to a change in that part of the Valuation Act which relates to the correction of the valuations from time to time. I have only one thing to say regarding that. I hope this Committee will succeed in securing some simplification in the requirements of Valuation Order No. 3. It is my opinion that that order should be entirely rewritten. If that cannot be accomplished at this particular time, I think it should be something to look forward to, because Valuation Order No. 3 is now in some five, six or seven different parts. It was written by many different people, and, as I see it, now is the time to bring about a great simplification in the requirements with reference to the collection of permanent data.

The misconception respecting the capitalization of the railroads which was in the minds of many people previous to 1913 continued for many years. This misconception was not only on the part of men who were prominent in politics; it also existed in the minds of some very prominent people who took great interest in civic work. I think that we made a great advance, Mr. Chairman, in the matter of public sentiment in the last twenty years respecting this particular subject.

Last May, when Congress had under consideration the Emergency Transportation Act of 1933, Mr. Eastman appeared before the House Committee on Interstate and Foreign Commerce and before the Senate Committee on Interstate Commerce and stated freely and frankly that the railroads were not overcapitalized. As I sat and heard Mr. Eastman make this statement, I said to myself, "Certainly that marks an epoch in the history of the discussion of this matter of the capitalization of one of the greatest industries of our country."

Subsequently, on January 20, 1934, Mr. Eastman sent to Congress the first part of the report which he was required to make, and in that first chapter he made a significant statement which I think should go into the records of this Association. Mr. Eastman stated (and this is all to be found in his first report):

"Contrary to much popular impression, the railroads are not in the aggregate overcapitalized, in the sense that the par value of outstanding securities exceeds the money invested in the properties. The Bureau of Valuation of the Interstate Commerce Commission has estimated that the original cost of railroad carrier property, other than land, as it existed on December 31, 1932, plus land valued as of June 1, 1933, and plus allowances for working capital, was in the neighborhood of $26,232,000,000. Original cost of lands is not known, but it was probably materially less than the value as of June 1, 1933. Making all due allowance for this fact, however, the original cost of railroad carrier property would not fall below $24,000,000,000. On December 31, 1932, the total railroad capital actually outstanding was $23,573,556,588, made up of $10,226,070,233 in stock and $13,347,486,355 in funded debt. Allowing for intercorporate holdings, the net capitalization outstanding in the hands of the public was $19,489,062,256, made up of $7,150,374,952 in stock and $12,338,687,304 in bonds.

"While there was much inflation of the original capitalization of many railroads, this has since been offset, in the aggregate, by two principal factors: (1) Much investment of surplus earnings in carrier property by the more prosperous railroads, and (2) the scaling down of original capitalization through reorganizations."

That is the statement of Mr. Eastman to the Congress of the United States, and it seems to me that it effectively disposes of the idea which prevailed twenty years ago that the railroads were overcapitalized. The fact is that the railroads are undercapitalized. These figures indicate that, and I might go farther and give additional figures which would prove this undercapitalization.

The Chairman of the Sub-Committee made the statement that many people thought that there would be no further need for valuation work after the change that was made by Congress in the Act last June. I endorse what the Committee said regarding that matter. In my opinion, the fundamental data which has been collected and which is on

file in the offices of the railroads will be of as much use in the future as it ever has been in the past and may be even more useful.

It is interesting to know that the Securities Act of 1933, which does not apply to steam railroads, requires all corporations in this country to have their securities passed upon by the Federal Trade Commission. The Securities Act of 1933 is so severe in its requirements that any Engineer who prepares a report on any corporation engaged in common carrier service, and fails to include a material fact or makes a misstatement of a fact is subject to civil liability; that is, he is subject to being sued at any time within ten years after the time he files his report. If he deliberately makes a misstatement in one of his reports he may be sent to jail for a number of years. The question of valuation is now important in connection with other corporate properties by reason of the Securities Act of 1933.

There has been in progress in Washington, D. C., during the past six months a joint conference on appraisal practices. I bring that to the attention of the Committee. The conference is voluntary. It is composed of Engineers, architects, real estate experts, life insurance representatives, bankers and appraisers.

This conference has under consideration the question of the essentials of appraisal reports, and the reason for the conference is the new practice which is prescribed by the Securities Act of 1933.

I rise to commend the Committee for the excellent work which it has done (Applause).

Chairman C. C. Haire: The Committee is very glad, as always, to hear from Mr. Wendt, who was formerly Chairman of this Committee and served on it for a good many years. His advice is always helpful.

The next subject to be presented by the Committee is Methods Used in Recapture Proceedings, Appendix I, page 618. Mr. Silliman, Chairman of the Sub-Committee, is not present. I will briefly call attention to the report shown.

Mr. Silliman has been acting as a sort of reporter for this Committee. Each year he has recorded what has taken place in the recapture field, and now that recapture has passed out of existence, the report as shown is merely to close the assignment. It is offered as information.

The President:—It will be so received.

Chairman C. C. Haire:—Under the next group of subjects, the first one is Appendix J, Developments under I.C.C. Order No. 15100. The subject is closely allied to the one on revision of the accounting classifications, but the revision of accounting classification subject is not reported this year as there have been no developments. However, there has been an important development in connection with the depreciation subject. Mr. Hande, Chairman of the Sub-Committee, will call it to your attention.

Mr. J. H. Hande (Baltimore & Ohio):—Since the publication of the very brief report on page 618 of this Bulletin, there has come to hand the Commission's order of February 5 in which the depreciation requirements with respect to equipment have been made effective, calling for the establishment of rates on or before September 1, 1934, and for the inauguration of depreciation-accounting under the Order on January 1, 1935. Postponement for one more year with respect to road has been granted.

This Sub-Committee is in a peculiar position in that it is not in position to report on its assignment until there is an official issue of the classification and until the provisions in Order No. 15100 are recognized by suitable amendments to bring it in line with the pending classification So we can do nothing further until those two orders are made final

It may also be called to your attention that the entire matter of negotiation with the Commission with respect to the classification and Order lies in the hands of the Rail-

way Accounting Officers' Association, and we are estopped from making any reports until they have concluded their arrangement with the Commission. These brief developments are offered as information.

The President:—They will be so received.

Chairman C. C. Haire:—The concluding report of the Committee is methods for avoiding duplication of effort and for simplifying and coordinating work under the requirements of the I.C.C. This subject has been carried along for a number of years. We call attention to the fact that we are alive to the need of simplifying and working out a procedure which causes the least expense to the carriers.

The report as shown on page 619, Appendix K, is a record of what has transpired. However, there is a small correction to be made in this report. I will ask Mr. Knowles to call it to your attention.

Mr. C. A. Knowles (Chesapeake & Ohio):—Since the writing of the report to which Mr. Haire has referred, certain developments have taken place. A number of Engineers, among whom are members of Committee XI of your Association, have been assisting the Committee on Valuation Accounting of the Railway Accounting Officers' Association in the preparation of certain reports illustrative of the minimum requirements of the provisions of Valuation Order No. 3 of the I.C.C. It is understood that these illustrative reports, when completed, will be circulated by the Railway Accounting Officers' Association among the carriers interested. The members of Committee XI who have been aiding in this work have not, however, been assisting as representatives of Committee XI.

Chairman C. C. Haire:—That concludes the report of Committee XI.

The President:—This Committee has had in the past and will have in the future assignments that are of great importance to the railroads. Their function is to keep the Association informed of these developments. The Committee is now excused with the thanks of the Association (Applause).

DISCUSSION ON ROADWAY

(For Report, see pp. 347–402)

Mr. Geo. S. Fanning (Erie):—The Roadway Committee's report will be found on page 347 of Bulletin 360. We had nine subjects assigned and are offering reports on five of them. On the first subject, Revision of Manual, we have nothing to report.

The second subject is Methods of Roadbed Drainage. You will find the report on page 348. This will be offered by Mr. H. M. Swope, of the Santa Fe.

Mr. H. M. Swope (Santa Fe):—This is the fourth year of this Committee's existence. Consideration of this subject has been continued in accordance with the outline adopted in 1931. The subject-matter developed by this Committee during the past three years has been adopted for publication in the Manual and is to be found in Proceedings, Vol. 32, Vol. 33 and Vol. 34. The following report concludes the study of this subject as outlined, and that portion of the report beginning with (C) Maintenance, page 348, to Recommendations on page 354 is recommended by the Committee for publication in the Manual. I so move.

The President:—It has been moved and seconded that the report as published, pages 348 to 354, be adopted and printed in the Manual. The motion is now before you for discussion. The Chairman desires to offer these by general subjects for discussion and amendment.

Mr. H. M. Swope:—(C) Maintenance; Maintenance of Ditches; Causes.

Mr. J. E. Willoughby (Atlantic Coast Line):—I think it might be of benefit if the Committee would give us some idea as to what they consider excessive grades for ditches and also insufficient grades for ditches.

Mr. H. M. Swope:—That has already been included in previous reports which have been adopted and are in the Manual.

Mr. J. E. Willoughby:—The Committee says: "Excessive grade tends to such rapid flow of water as to scour the bottom," etc. Some reference ought to be made as to what the Committee considers an excessive grade, by means of reference to other reports, if the information be contained in some other report.

Mr. H. M. Swope:—The first report of this Committee which is included in the revisions and additions to the 1929 Manual I believe includes what you have in mind. Of course, in the publication in the Manual this material will all be together in order, and this merely is a part of the report.

Mr. J. E. Willoughby:—I should think the Committee might make some references by note as to where the excessive grades and insufficient grades may be defined.

Mr. H. M. Swope:—We will take care of that.

Maintenance—1. Shallow Cuts, 2. Deep Cuts.

Under Deep Cuts I have received a written discussion from Mr. E. E. R. Tratman, which I will read: "In reference to the drainage of deep cuts, page 349, apparently the 'auxiliary track' mentioned is not of standard gage but is to be the narrow-gage equipment generally termed 'industrial' or 'portable' track. It may be well to modify the wording to: 'Industrial track of small gage, with small cars, may be used,'" etc.

It follows that where this method can be employed, it usually would be necessary to use the narrow gage. However, this is not always true, and I do not believe it should be specified in the Manual for that reason. This written discussion follows:

"During a trip to England last summer I noted numerous cases where deep cuts had drains of rough stone paving with squared blocks, laid up the slopes. The width would be four or five feet and between each pair of drains would be a similar longitudinal drain, not horizontal, but inclined as a flat V, with its apex midway between the two drains up the slope."

The drains in deep cuts which Mr. Tratman mentioned are to drain the slopes of wet cuts and is offered by him as information.

Ditching Machines. Maintenance of Drains. Pipe Drains: General, Inspection, Markers, Outlet ditch, Outlet pipes, Overflow, Flushing, Vegetation, Failure.

French or Rock Drains: Outlets, Outlet ditches, Silting.

Special Problems of Maintenance. Soft Spots and Water Pockets: Occurrence, Importance, Treatment. Slides: Definition, General.

That concludes the report by headings.

The President:—Is there any discussion on this motion? The motion is on the adoption of the subject-matter on Roadbed Drainage, pages 349 to 354. All those in favor will say "aye"; contrary. It is carried and so ordered.

Mr. H. M. Swope:—In order that existing material in the Manual pertaining to Roadbed Drainage be made to harmonize with this Committee's report, it is the recommendation of the Committee that the following changes be made in the 1929 Manual:

Page 23. Remove definition of slide.

Page 25. Under "drainage" add definition: French Drain—Underground passages for water through the interstices among stone placed loosely in a trench.

Make the following revision to "Specifications for the Formation of the Roadway", pp. 28 to 36, inclusive: Page 31. Add the following to Section 30, "Intercepting Ditches": "The material excavated from the ditch shall be deposited on the side of the

ditch towards the cut, unless otherwise directed. The slope of the waste bank from its summit towards the ditch shall be as long as feasible. In crossing light depressions in hillsides, when directed, levees shall be constructed and the depression filled above the levee so as to bring its surface up to the grade of the ditch. The top surface of this fill shall be of puddled clay.

"Intercepting ditches, when ordered, shall be made on the upper side of the fills where the ground slopes towards the embankment. The cross-sections and locations of such ditches shall be designated. Unless otherwise ordered, the waste dirt shall be placed so as to provide a slope from the toe of embankment to the ditch. If required, they shall be excavated in advance of the construction of the embankment."

Pages 31 and 32. Replace all of Section 32, Subdrains, with the following:

"Pipe subdrains shall be constructed of the material and size and in the location shown on the plans, or as directed, and to the depth and grade established for them. The cross-section of the trenches shall conform with the plans, and the trench shall be excavated and the pipe laid to true line and grade. Sufficient cribbing or shoring must be used to prevent caving of the trench excavations. All trenches shall be backfilled with an approved permeable material, kept free from dirt, dust and other foreign material. The finished section of the backfill shall conform with the plans."

Page 33. Add the following to Section 40, "Finishing Subgrade": "It must be maintained in this condition until the ballast is placed (or until accepted). Any backfilling necessary to make a smooth surface shall be made of the same material as exists in the roadbed.

"Where roadbed, in either cuts or fills, is composed of a more or less clay material, all construction tracks shall be removed after the work has been brought to grade and the subgrade rolled with a road roller weighing about 10 tons and thus brought to proper crown and surface."

Page 40. Remove all material under "Slides", Articles 1 to 12, inclusive.

Page 41. Replace Fig. 2 with two plates illustrating roadbed drainage.

Page 46. Remove "Means for Prevention or Cure of Water Pockets in Roadbed", Articles 1 to 6, inclusive.

Page 50. Remove all material under "Soft Spots".

Pages 50, 51 and 52. Remove all material under "Ditching".

I move that these changes in the 1929 Manual be adopted.

The President:—Is there any discussion? All those in favor of adopting these recommended changes say "aye"; contrary. It is carried and so ordered.

Chairman Geo. S. Fanning:—Our third subject is on the service life and specifications for railway fence wire. Our Sub-Committee has been cooperating with the American Society for Testing Materials and hopes to have a final report during the coming year.

On the fourth subject, practice of jacking culvert pipe, you will find the report on page 355. This will be presented by Mr. O. H. Wainscott, of the Illinois Central, in the absence of the Chairman, Mr. Noble.

Mr. O. H. Wainscott (Illinois Central):—In making this report the Committee had in mind providing the source of information for those unfamiliar with work of this kind, from which they could secure sufficient data to prepare an estimate of the cost and also enable them to select some suitable method to carry out the work. It is the recommendation of the Committee that this report be received as information and the subject be discontinued.

The President:—Is there any discussion on this subject? It occurs to the Chair that this is subject-matter for the Manual, and I may ask the Committee why they are not recommending it for the Manual.

Chairman Geo. S. Fanning:—This subject is rather new, and we would like to have

our recommendations tried out for a few years, and then we will ask that the subject be reassigned and then put it in shape for the Manual.

The President:—Unless there is objection, we will handle it in that way.

Chairman Geo. S. Fanning:—Our fifth subject is Bearing Power and Other Physical Properties of Soils, including Effect Upon Roadbed. The report will be found on page 364. It will be offered by Mr. E. R. Lewis, of the Michigan Central, in the absence of Mr. Legro.

Mr. E. R. Lewis (Michigan Central):—The information contained in this report is preliminary to a presentation of principles which the Sub-Committee is engaged in materializing in its study, as well as data concerning developments, particularly of the past few years. It includes soil terminology in which a more complete description of terms is given than may be convenient to include in the body of future reports using these terms.

The report is offered as information.

The President:—Is there any discussion on this report? I would like to call attention to the fact that this subject is one of the subjects selected by the General Committee of the Engineering Division for report. It is considered a very important subject, and the Committee has made a start on it. I am sure they will be glad to have any suggestions that the membership may have to offer. It will be received as information.

Chairman Geo. S. Fanning:—Our sixth subject is on Methods of Protecting Against Drifting Snow and Opening Snow Blockades. The report will be found on page 370. It will be offered by the Chairman of the Sub-Committee, Mr. F. W. Hillman.

Mr. F. W. Hillman (Chicago & Northwestern):—Last year this Committee presented a report on "Methods of Protecting Against Drifting Snow and of Removal of Snow on the Line and in Yards and Terminals" as information, with a recommendation that this subject be reassigned. In the reassignment there was a modification made of the subject as indicated. The Committee collaborated with Committee XXVII—Maintenance of Way Work Equipment, as instructed. The report follows on page 370.

There has been no attempt whatever to give any specific recommendations because of the fickleness of snowstorms, and only general rules have been suggested.

The report is divided into two sub-divisions as suggested by the title, first, Protection Against Drifting Snow. Mention is made of the necessity of removing obstructions, and also of placing obstructions such as the fixed and portable fences. It has been suggested that a diagram or sketch indicating the slat and wire type fence be included in the Manual. This was discussed at length in the Committee, and it was decided that as this type of fence is so commonly known we would not burden the Manual with another sketch.

The next sub-division is Opening Snow Blockades. This is divided into the general statements—the necessity of keeping the line open, and the precautions that should be taken by the general officers in keeping in touch with the men. Then there are suggestions for handling blockades on the line and in yards and terminals. There is an error under "In Yards and Terminals" in the third line of the last paragraph on 375. The word "of" should be crossed out. This report is submitted for publication in the Manual, and I so move.

The President:—It has been moved and seconded that this report be adopted as recommended practice and included in the Manual. That motion is now before you for discussion. I will ask the Chairman to give you the opportunity to discuss each part of the report by reading the captions.

Mr. F. W. Hillman:—Protection Against Drifting Snow.

Mr. J. E. Willoughby (Atlantic Coast Line):—In the heading "Permanent Snow Fence, Open Boarding," there is not designated the character of material that that fence

be built of in order to make it permanent. What is meant, I take it, is a fence in a fixed location.

Mr. F. W. Hillman:—What paragraph?

Mr. J. E. Willoughby:—Page 372.

Mr. F. W. Hillman:—That was accepted in the Manual several years ago, and we have not seen fit to change it.

Mr. J. E. Willoughby:—Does the Committee maintain that a snow fence built of ordinary pine boards is a permanent fence?

Mr. F. W. Hillman:—I think anybody who would so consider it would be foolish. Probably the word "permanent" is wrong and it should be "fixed," but that has been adopted in the past. It seems to have served the purpose, and to indicate what we mean.

The President:—I suggest that the Committee on Manual consider that item and edit it properly.

Mr. F. W. Hillman:—Opening Snow Blockades: General; On Line; In Yards and Terminals.

The President:—Is there any discussion on this subject? Are you ready for the question? The question is on the adoption of the report as printed, pages 370 to 376, inclusive, as recommended practice and for inclusion in the Manual. All those in favor will say "aye"; contrary. It is carried and so ordered.

Mr. E. E. R. Tratman (Civil Engineer):—In regard to snow fencing, since the slat-and-wire type is stated, on page 371, to be replacing other portable types mentioned, it would be useful to illustrate this as well as the other types.

Chairman Geo. S. Fanning:—The seventh subject is on Specifications for Galvanizing Metal Culvert Pipe. Progress is reported on this subject with a recommendation that the subject be broadened to include a complete review of the Specifications for Corrugated Metal Culvert Pipe. This is being done by the 1934 Committee.

Our eighth subject is service life of culverts. This is a new subject this year. The Committee reports progress in organizing its work.

Our final subject is on methods of protection against drifting sand. This will be found on page 376 and will be offered by Mr. C. W. Baldridge, the Chairman of the Sub-Committee.

Mr. C. W. Baldridge (Santa Fe):—The subject "Methods of protecting against drifting sand," is one problem with which many railways do not have to contend, but which, on many other railways, as well as on many highways, irrigation ditches, sea coasts, and other places, is a very serious problem.

But little effort seems to have been made in the past to secure and make available information regarding protection against drifting sand. Seemingly, most people have regarded the problems resulting from the drifting of sand and dirt to be the same as those arising from drifting snow, but this is far from the case in one important particular, that being that protection against drifting snow must take care of the drifted material for one winter only, the summertime removing the drift entirely, while a drift of sand once made must be removed by artificial means or be lived with always.

The responses to the requests for information made by members of the Committee were very gratifying, and they show a very wide interest in the subject. In some cases, the responses have carried practically identical information. Therefore, in such cases, while all the papers received are much appreciated, but one is published. Some excellent reports in which some new features were presented, were received after the Committee's report had been sent to the Secretary for printing. Such reports are in the hands of the Committee and will be handled in the coming year's work.

To all those who have sent information to us, the Committee extend their thanks.

The matter in this report from pages 376 to 401 is offered as information. The conclusions beginning on page 401, and reading as follows, are offered for inclusion in the Manual:

"1. Protection against drifting sand, as is the case with snow, should begin with the construction of the road, be it railway or highway.

"2. Wherever drifting or blowing sand is probable, the roadway should be constructed above the natural ground level where possible and all obstructions which might cause the deposit of sand should be removed and the embankments faced with clay, oiled sand or some other substance which will provide a smooth surface, thus allowing the blowing sand to keep on moving, thereby avoiding drifts.

"3. If cuts cannot be avoided, they should be constructed with flat, smooth slopes and the drifting of the sand controlled by the construction of open-bottom wind chute fences as shown on page 400 of Volume 35 of the Proceedings.

"4. On existing lines the same remedies should be used where applicable.

"5. Wherever sand drifts occur between the rails of a railroad track, the ballast should be cleared out to a half skeletonized condition, to permit the wind to pass under the rails, thus clearing the sand away.

"6. Where the source of the blowing sand can be controlled by the planting of vegetation, such treatment may be the most economical method of protection, and should be considered.

"7. Where moving sand dunes exist they sometimes may be dissipated by the scattering of gravel or small stones over the face of the windward slope.

"8. Where trouble is experienced from sand blowing out of embankments, thus undermining the track, or from its blowing out of the sides of cuts causing slides or other damage, the proper remedy is usually the covering of such surfaces with a layer of clay or other stable material.

"The Committee recommends that the above conclusions be adopted for inclusion in the Manual." I so move.

(The motion was regularly seconded.)

The President:—It has been moved and seconded to include these conclusions in the Manual as recommended practice. It there any discussion? All those in favor will vote "aye"; contrary. It is carried and so ordered.

Chairman Geo. S. Fanning:—That concludes the report of the Roadway Committee.

The President:—As usual, this Committee has presented a very valuable report. They will now be excused with our thanks (Applause).

DISCUSSION ON CLEARANCES

(For Report, see page 675)

Mr. A. R. Wilson (Pennsylvania):—This report is found in Bulletin 363, page 675. The diagram in the report has been before you for a year, it being presented last year. This diagram representing the outline of the proposed box car was prepared by the Mechanical Division of the American Railway Association. That Division and several other Divisions have held several conferences, and, under the direction of the A.R.A. a questionnaire was issued to all members and associate members of the American Railway Association.

In studying the questionnaire and compiling the results it was found that a car built to these dimensions can be operated over 97½ per cent in interchange service of the railroads in this country and Canada.

The questionnaire also developed that there were a number of pieces of equipment exceeding this outline, nearly 11,000 locomotives exceeding this outline, however, locomotives are not used in interchange service. This diagram will continue the series that

this Committee presents from time to time supplementing Fig. 1, 2, 3, 4 and 5 which have been adopted by this Association and appearing in other Bulletins.

A suggestion reaching the Committee too late to have a committee meeting suggests to us that we change somewhat our recommendation, deleting all information or reference to a proposed A.R.A. box car, our report which is presented for adoption in the Manual reading, "that the limiting equipment diagram for interchange service, Fig. 6, be approved and printed in the Manual." This change in the title of the diagram is consistent with the assignment to this Committee.

I move that this diagram be approved as the limiting equipment diagram for interchange service.

The President:—You have heard the motion, gentlemen. Is there any discussion? All those in favor say "aye"; contrary. It is carried.

Chairman A. R. Wilson:—This concludes our report, Mr. President.

The President:—The information presented by this Committee is timely and valuable. They are now dismissed with the thanks of the Association (Applause).

DISCUSSION ON BALLAST

(For Report, see pp. 663–670)

Mr. A. D. Kennedy (Santa Fe):—The report of this Committee is given on pages 663 to 670 of Bulletin 362.

The first assignment is Revision of Manual. The Committee has a few recommendations to make in this particular but it will be handled in connection with the report of the Sub-Committee on Assignment No. 6, Appendix D.

The next assignment is Specifications for Prepared Gravel Ballast, Including Best Method of Testing for Hardness, Abrasion and Resistance to Weathering. The report will be submitted by Prof. Foster, in the absence of the Chairman of the Sub-Committee.

Prof. W. L. Foster (Iowa State College):—The Committee has no new information to offer at this time. Last year the work consisted of correlating the data previously secured. However, sufficient correlation has not been found to exist between the laboratory test and field observation, and the Committee feels that more information must be collected and analyzed before definite recommendations can be made. It is recommended, therefore, that the subject be continued and that the Association have patience until economic conditions improve.

The President:—The subject will be continued.

Mr. A. D. Kennedy:—The next assignment to the Committee is Specifications for Stone Ballast, Including Best Method of Testing Resistance to Weathering (Appendix B). The report will be presented by Mr. Podmore, Chairman of the Sub-Committee.

Mr. J. M. Podmore (New York Central):—Last year your Committee submitted as information an alternate method for making an abrasion test on crushed stone as produced for ballast, known as the Modified Abrasion Test. Before recommending the adoption of this test, it seems desirable to await developments from a series of tests which largely have been completed on still another modified form of abrasion test, making use of the so-called Los Angeles Rattler. Your Committee recommends that the test for abrasion be given further study.

Last year your Committee recommended that the section dealing with cementing value be removed from the Specifications for Ballast. However, by instructions from the convention the subject of cementing value has been given further study. During the past year a questionnaire was sent out to railroads. Answers were received from 58 railroads, six of which advised that the cementing value tests were used by those roads. The

test requirements specified by the six roads using the cementing value test varied all the way from 1 lb. to 450 lb. per sq. in.

In view of the wide variation in specifications of the six roads using the cementing value test, it is evident that an inconsistency exists. Because of this inconsistency it seems desirable to initiate a cooperative series of tests which will shed light on this entire matter of cementing value of rock for use as railroad ballast.

Your Committee is taking steps to initiate a cooperative series of cementing value tests with objectives as already indicated, with the hope of obtaining information of practical value for use in Specifications for Ballast.

The above report is recommended as information and the subject be continued.

The President:—The Committee would like some discussion on this specification. The specification will be received as information and printed in the Proceedings.

Mr. A. D. Kennedy:—The next assignment is Comparative Costs of Maintaining Track on Various Kinds of Ballast. The Sub-Committee has rendered a report which is shown under Appendix C on page 667. This is to be considered as a progress report, and they wish to advise that an earnest effort will be made to have a specific test installed on one or more railroads to bring out some dependable data on this subject. The Committee reports progress and wishes the subject to be continued.

The President:—Is there any discussion on this subject?

Mr. A. D. Kennedy:—I would say, however, the Committee would sincerely like to have some suggestions on this subject.

The President:—The subject will be continued.

Mr. A. D. Kennedy:—The next subject of the Committee is Effects of Different Kinds of Ballast on Life of Ties, on Life of Rail and Upon Rail Failures, particularly as between gravel and crushed stone ballast. The Sub-Committee assigned to this subject reports progress, and we would like to have the subject continued for further study.

The President:—It will be so received.

Mr. A. D. Kennedy:—The next assignment of the Committee is to determine proper depth and kind of sub-ballast. This subject has been before the convention for a number of years, and the report of the Sub-Committee is shown in Appendix D on page 668.

The report, in a measure, is fashioned after suggestions made on the floor of the convention last year, in that the first portion of the report is devoted to a historical review of what has gone before on this subject, and this historical review is concluded by quoting what is now included in the Manual under the heading of "Proper Depth of Ballast."

The Sub-Committee has spent considerable time in studying this subject, but we regret that we can only bring a negative report to this extent, and this is embodied in the report in Appendix D on page 669:

"The thickness or proper depth of sub-ballast to use depends upon sundry conditions and variables. Experienced Engineers, after acquainting themselves with all the conditions to be encountered, should be able to approximate the proper depth to use."

In our research we were unable to support any specific depth of sub-ballast, and the Sub-Committee continues as follows:

"For lack of definite information regarding the many existing and ever-changing conditions particular to each location, your Committee feels this Association cannot defend, except by opinion, a ballast section of any specific dimensions. However, there is information contained in the Proceedings of the Association, reference to which is given in this report, which, if intelligently interpreted, would be a guide in determining both the proper depth of ballast and sub-ballast to use in any particular location."

That is the finding of the Sub-Committee.

The President:—Is there any discussion on that part of the Committee's report?

Mr. J. B. Jenkins (Baltimore & Ohio):—The Committee makes the statement: "After years of service, the sub-ballast of an original ballast section loses its identity as such. It becomes so mixed with the subgrade that a distinction is impossible."

In connection with the valuation inventory of the railroads, trenches were dug through the old ballast about every thousand feet, and it was the exception rather than the rule to fail to find a very marked line between the ballast and the subgrade. In only a small minority of locations did the ballast or sub-ballast get mixed with the subgrade.

Mr. Frank Ringer (Missouri–Kansas–Texas):—I would like to support what Mr. Jenkins just said. Some years ago we had an occasion to make quite a series of tests along that very line. It was the marked exception rather than the rule where we were not able to establish a clear line between the sub-ballast and the original roadbed material.

Mr. J. C. Irwin (Boston & Albany):—I want to endorse this idea that the conditions are not always as stated in this report, and it is too general to be taken as a common situation.

On our New England railroads, particularly, where we have a good subgrade, wherever we cut out for a bridge or culvert and get an original cross-section, we get a beautiful definition between the sub-ballast and the top ballast without any settling of the sub-ballast into the subgrade at all. On the other hand, in clay formations, particularly in soft clay fills, the ballast does work down into it, but I think we have to recognize the fact that it depends entirely upon local conditions. I have seen some sections which I might say are seventy or eighty years old where you can find the demarcation between the various kinds of ballast very clearly.

Mr. C. W. Baldridge (Santa Fe):—I believe the statement this Committee has made is that the depth of ballast as now recommended in the Manual seems to be based entirely on opinion.

A number of years ago the Special Committee on Stresses in Track gave us a report in which they gave charts showing the stresses and pressures developed in ballast in roadbeds. It was quite an extended report and a very excellent study.

The Ballast Committee, following that report, used the information given in that report of the Stresses in Track Committee, to find the required depth of ballast. Unless this Committee have something better to offer than what is in the Manual I would oppose making any change at this time.

The President:—The Chair was just about to mention that the report of Dr. Talbot on Stresses in Track, as Mr. Baldridge has pointed out, contains some very valuable information on which the Committee can substantiate their conclusions. Dr. Talbot is present, and I would like to have him say something on this subject.

Dr. A. N. Talbot (University of Illinois):—I am not generally critical, but I may say that I am disappointed in the Committee's report on the function and value of ballast. It is more in what the report does not say than in what it gives. The statement for insertion in the Manual says: "Depth of ballast should exceed the minimum required to uniformly distribute superimposed loads to the subgrade without causing its deformation."

Of course, that would be accepted as a generality—but how much should it exceed the depths given in the standard ballast sections in order to cover the unevenness and variations that may occur along the railroad in the way of drainage and in variety of materials below the ballast? What kind of subgrade does this refer to? Is it one that is always drained and is solid and substantial, as was referred to by someone just now, or is it thought that the ballast serves principally to drain and take the water down to material just below, which with this water may become wet and mucky and easily de-

pressed by uneven pressures? Is there any factor of safety provided for the unknown and occasional conditions of the subgrade? What variations may be expected?

In the Second Report on Stresses in Track it is shown that instead of the distribution of pressure away from the tie width beginning at the bottom of the tie the lines of pressure first incline inwardly and not outwardly as is usually assumed, so that at a distance of 5 or 6 in. below the bottom of the tie the concentration of pressure is materially greater than it is immediately under the tie. Below this level the lines of pressure diverge so that at a distance of 10 or 12 in. below the bottom of the tie, the distribution of the pressure is not particularly different in intensity from that existing at the bottom of the tie. Below this level the lines of pressure continue to diverge and for the ordinary tie spacing at 18 or 20 in. down the distribution longitudinally of the track is fairly even, provided the material below is uniform and will support the load coming on it under all conditions whether wet or dry. The foregoing is a necessary condition of granular material, which I think we must accept.

In addition to drainage, the upper part of the ballast then acts as a sort of mechanism to transmit the pressure down to where it will spread out further (see Fig. 95 to 100, Second Progress Report of the Committee on Stresses in Railroad Track, Proceedings A.R.E.A., Vol. 21, 1920). Doubtless, much of this mixing of materials which has been spoken of in the discussion occurs by reason of an inadequate depth of ballast being applied at the beginning, not sufficient depth to cause the pressures to spread out so that the lines of pressure between the ties will meet within the depth of the ballast. The concentration of pressure under a tie should not be such as to permit the ballast to be forced down into the material below, especially when this lower material is wet and cannot support high concentrated loads. The larger particles of ballast may be forced down into the subgrade, but this is much more likely to occur with shallow ballast than with an adequate depth.

The question may well be raised whether 12 in. of top ballast is sufficient. The question may also be raised whether the methods ordinarily used of adding a few inches of ballast at a time, before a sufficient depth is applied, are effective in realizing the best value of ballast.

What is there in the report to give an idea of when the mixture of ballast and dirt, referred to in the discussion, is sub-ballast and when is it merely subgrade? Is there any thing to indicate what is to be called the top-ballast and what the sub-ballast?

In the diagram in the Manual the depth of 12 in. of top-ballast and 12 in. of sub-ballast has no definition, nothing to tell what is meant by these terms. In the diagram for Class B Track, the minimum depth is given as 9 in. under the ties, and this is recommended for the firmest, most substantial and well-drained subgrades. Should there be given a warning that this depth does not provide an even distribution of loading on the subgrade along the track? What is to be done for less substantial subgrade?

In the diagram for Class C Track there is 6 in. of material; this will give some drainage of the ballast. This depth, however, does not give distribution of pressure—rather a concentration. Under traffic it may be expected to be easily forced down into the subgrade.

Would it not be well to give something on the function and value of ballast other than that of drainage? Cannot something be said on principles relating to the lateral and vertical distribution of pressure downward through ballast? What mixtures of gravel or broken stone with dirt can be called ballast? Will depths of ballast beyond those that may be expected to provide fairly uniform distribution over an excellent subgrade be desirable as a margin of safety against the variability of subgrade conditions from point to point along the track? Is it too much to ask if an attempt should not be made to prepare something that at least will give a clue to the advantages of deep

consolidated ballast (beyond the minimum depths) which can be used in evaluating the extra expenditure—the added stiffness and stability of the track structure and the decreased cost of maintenance?

Is the Committee on Ballast lukewarm on the value of ballast?

Mr. A. D. Kennedy:—I will say this, on behalf of the Committee, that the Committee has recognized in their discussions and in their conferences the objections that have been raised on the floor, but, nevertheless, after lengthy research we have been unable to get definite information that would enable us to make a definite recommendation as to proper depth.

The idea in making this report is to make it rather general so as to leave it to the opinion of the Engineer in charge. In this particular we have made particular reference to the history of the subject in the Association and called attention to matters that would help them in making a decision. In this particular we call attention to the discussions of the Committee on Stresses in Track.

I still feel that the Committee has complied with their present instructions, and I also feel sure that the Committee cannot go any further into this question unless an appropriation is made by the Association to install a special test. We have exhausted all our information in this particular. If any of the members either present or not present can give us any definite clew that we can follow, we will gladly accept it.

This question of the proper depth of ballast has been before the Association since 1907, and it is still unsolved. As I said before, we welcome any specific suggestions.

Mr. C. W. Baldridge:—The question has been before this convention longer than that, about thirty-five years, in fact. It was thrashed over very thoroughly a number of times. When the matter which is now in the Manual, recommending 12 in. of sub-ballast and 12 in. of top ballast was adopted, it was after a great deal of discussion and study. Unless this Committee can offer us something to put in the Manual, more than telling a man to use his judgment, we might as well leave it out. A man can use his judgment without a Manual. I believe that the Committee's recommendation of a substitute for what is now in the Manual should be rejected.

Mr. A. D. Kennedy:—I will say in reply to the last speaker that I do not for a moment wish to be contradictory to the general opinion, but I have made a survey of all the Proceedings of the Association since 1902 and I have failed to find where the Association or the Committee has been justified in making the recommendation that is now shown in the Manual.

For your information, under the heading "Proper Depth of Ballast" which is now shown in the 1929 Manual on page 102, it reads as follows:

"(1) On a roadbed material such as clay, loam, etc., subject to deformation by the application of live load, the proper depth of ballast under the tie to produce approximately uniform pressure on the roadbed, should be not less than the spacing center to center of the ties. For Class A Track, see Ballast Sections.

"(2) On material that approximates the character of good sub-ballast (which will not be deformed by the application of live load), the minimum depth of ballast under the bottom of the tie should be twelve (12) in.

"(3) These depths are required, under the conditions named, to support the track structure; to provide good initial drainage; to reduce upheaval by frost; to serve as a cushion for the track."

I am going to skip (4) and cite (5).

"(5) Until sufficient tests are made under normal traffic conditions, the proper depth of ballast under the tie must rest on opinion, based on experience and supported by such tests as are available, notably the test made by Director Schubert of the German Railways and the 'Altoona Test' made by the Pennsylvania Railroad."

So you see that paragraph (5) nullifies the previous recommendations that are contained in the Manual.

Mr. C. W. Baldridge:—I fail to agree with the gentleman that Section (5) nullifies what went before. The three paragraphs read, make a definite recommendation, and if those steps are not sufficient, then Paragraph (5) would control. Paragraph (5) is, in reality, going beyond the depths that are recommended and does not cancel any previous recommendations.

Mr. A. D. Kennedy:—That is purely a matter of opinion. The opinion of the Committee is to the effect that it does contradict paragraphs (1) and (2). Paragraph (3) reads, as I said before:

"These depths are required, under the conditions named, to support the track structure; to provide good initial drainage; to reduce upheaval by frost; to serve as a cushion for the track."

You will agree that paragraph (3) is covered by the definition of ballast previously quoted in the Manual. Paragraph (6) reads:

"Proper drainage of the subgrade is essential to success with any kind of ballast."

That is self-evident.

Mr. H. L. Ripley (New Haven):—What is now in the Manual was put into that Manual some twelve or fifteen years ago while Mr. Baldridge was a member of that Committee and, I think, while I was Chairman of that Committee.

I think it is going a little beyond a statement of fact when you say that it rests entirely on opinion, because the Altoona test made by the Pennsylvania Railroad was quite an extensive, if not exhaustive, test, and the studies made in Germany also were made on what was considered a scientific basis and were very helpful to the Committee. There were other tests made at the time. I want to support what Mr. Baldridge has just said, that those depths, and particularly that language used; that, in order to support the track properly, the depth of ballast should not be less than the spacing center to center of ties, was not based merely on opinion, although opinion was sought, and very extensive opinions were expressed by those who were familiar, through long practice, with the actual experience of ballast.

The basis was the tests that had been made, supplemented by the opinions which we sought, and got, from experienced Maintenance Engineers at the time.

I also want to support what Mr. Baldridge said about paragraph (5); that it covered cases where it was found that the depth of ballast below the bottom of the tie, when tried or tried under similar conditions, was found to be insufficient. That is particularly true in some of the clay countries, and on some of the material which we have up in New England which goes by the colloquial name of "bull liver," a quaking mass, where experience has shown us who have had to deal with it that sometimes we have to go down three and four feet in order to get a proper depth of ballast under the tie, not perhaps to support it for the first day but so that it will not pump up through the ballast but will stay as ballast and not become an aggregate of earth and ballast, and, eventually, not materially better than the poor soil found below the ballast line.

Mr. John V. Neubert (New York Central):—I may be out of order, but I believe the idea is to withdraw that which is now in the Manual specifying the depth of ballast. Is that correct?

Mr. A. D. Kennedy:—Yes.

Mr. John V. Neubert:—I am objecting to that because I believe that in the railroad field today, with various kinds of ballast and traffic conditions, we should know what is known as the minimum depth. Irrespective of what you may think, I believe

your Committee is well qualified, from practical experience and knowledge, as to what they would recommend.

If you feel you should have some research in regard to making an investigation of what the proper depth of ballast should be, I think you should go back to the Board to help you obtain that information. The reason I am bringing that out is I believe the Board has appointed a special committee, and your Committee is represented on that special committee. The common expression is that a railroad track is as good as its ties. How are you going to support that tie unless you have some ballast? As brought out forcefully by Dr. Talbot, not only in one of his reports but in many of them, ballast is essential to the upkeep, and the proper upkeep of your railroad. I would be opposed to withdrawing that from the Manual. I think you fellows can handle it, and I know you can handle it.

The President:—I think we have been getting a little ahead of ourselves. In other words, we have got the cart before the horse. The intention of the Committee, as I understand it, is to substitute some matter for that already in the Manual. There has been no motion to do that.

If, in the light of this discussion, the Committee still feels they are warranted in substituting this matter for that in the Manual, I think the time is now appropriate for a motion to that effect.

Mr. A. D. Kennedy:—I will make the motion, and I am still of the opinion that what is now in the Manual is erroneous, regardless of what we are going to substitute for it, with due respect to the members of the committees which have gone before, the fact that the language used in paragraph (5) does nullify the previous paragraphs because it states: "Until sufficient tests are made under normal traffic conditions, the proper depth of ballast under the tie must rest on opinion."

In lieu of the six paragraphs under "Proper Depth of Ballast" your Committee recommends the following:

"(1) There is a relationship between several conditions, viz., rail section, ties, tie spacing, kind of ballast, speed, wheel loads, drainage, subsoil, kind of traffic, etc., and the depth of ballast. Depth of ballast should exceed the minimum required to uniformly distribute superimposed loads to the subgrade without causing its deformation. Available data does not support a definite specification with reference to required depth for general application under all conditions.

"(2) In new construction a combination of good sub-ballast and top ballast does, with few exceptions, produce better results than a superior material used for the full depth. The ratio of the one to the other and the total depth in the aggregate should be determined with due consideration given to local conditions, as outlined in paragraph 1."

Then we give a note: "In the absence of more specific data, the tests made by Director Schubert of the German Railways (Vol. 7, pages 104 to 127) and by the Pennsylvania Railroad (Vol. 13, pages 95 to 265), although not conducted under regular traffic conditions, are of great value as a guide in determining the depth of ballast required for any given section of track.

"Reference is also made to Vol. 12, Part 1. On page 341 are given some of the conditions on which depend the proper depth of ballast and in Appendix A, page 345, is given the depth of ballast used at that time by representative railroads."

I move that what I have quoted here be included in the Manual and what now appears under "Proper Depth of Ballast" in the Manual be withdrawn.

The President:—It has been moved and seconded to include this subject-matter in the Manual in lieu of the present subject-matter. Is there any further discussion on the subject?

Dr. A. N. Talbot (University of Illinois):—May I ask whether this motion implies also that the ballast sections shown on pages 103 and 104 of the Manual are to be retained without any modification, and why it is stated in the paragraph of the report following what has just been read that the sections do not admit of any modification? Does this refer to depth of ballast regardless of conditions?

Mr. A. D. Kennedy:—For the information of the last speaker, the captions on these sections are to be revised, and I will presently make a motion to that effect, that they will admit of modification.

Mr. Edwin F. Wendt (Consulting Engineer):—I would like to amend this motion by striking out all after the first word and substituting the following: That the subject be referred back to the Committee for further study in the light of the discussion from the floor today.

The President:—The question before the house is on the recommitment of the subject.

Mr. J. C. Irwin (Boston & Albany):—My thought is we are on the way to the solution of such problems as this through action already taken. To begin with, the chairmen of the committees have been asked during the year to give the Board any recommendations that they may have in regard to research or tests which may be necessary for them to solve their problems. I think that would be the first thing for this Committee to do in order to get more definite information.

Further than that, we have recently formed the Committee on Complete Roadway and Track Structure for the very purpose of bringing together the various elements of roadway and track and being able to solve problems which involve a combination of all elements. In that connection, the Roadway Committee is studying the bearing power of soils. It has a very distinct bearing on the depth of ballast and the relation between the sub-ballast and top ballast.

In that connection, I think the motion to refer back to the Committee is very suitable. It will be further investigated through that Committee in that way as well as being considered by the new Special Committee on Complete Roadway and Track Structure.

The President:—The question before the convention is on referring this matter back to the Committee. Is there any further discussion? Are you ready for the question? All those in favor will say "aye"; contrary "no." It is carried and so ordered. That motion therefore voids the original motion for adoption.

Mr. A. D. Kennedy:—The last subject of the Committee is Effect of Better and Deeper Ballast on the Cost of Lining and Surfacing. The Sub-Committee on this assignment reports progress.

That is the extent of the Committee's report.

The President:—This Committee has done considerable work in spite of the fact that the subject is being referred back to them. They are now dismissed with the thanks of the Association (Applause).

DISCUSSION ON TRACK

(For Report, see pp. 923–955)

Mr. C. J. Geyer (Chesapeake & Ohio):—The report of the Committee on Track will be found in Bulletin 364. Your Committee reports this year on fifteen subjects.

Appendix A, Revision of Manual, begins on page 924. The first subject in the Revision of Manual is, that the material shown under the headings "Table of Dimensions for Tie Plates" and "Data for Designing Tie Plates", on page 251 of the 1929 Manual, be withdrawn.

I so move.

The President:—You have heard the motion. Is there any discussion? All those in favor will say "aye"; contrary. It is carried.

Chairman C. J. Geyer:—The second subject on Revision of Manual, the Committee proposes as recommended practice, that the design of cut track spikes, appearing in the Manual at page 254, be revised as follows:

The elimination of the dimensions which provide for optional lengths of spikes and in substitution therefor incorporation of dimensions providing for a single length of 5-½ in. between the throat and point for 9/16 in. spikes, and a single length of 6 in. for ⅝ in. spikes.

I move the approval of that.

The President:—Is there any discussion? Mr. Geyer might explain that the present spike shown in the Manual, I believe, is 5-½ to 6 in.

Chairman C. J. Geyer:—The present information on spikes in the Manual permits lengths of both 5-½ and 6 in. for both the 9/16 and the ⅝ in. track spikes. It is now simply proposed, for simplification, to furnish those two spikes in one length each only.

The President:—Is there any discussion on the subject? All those in favor of the motion will vote "aye"; contrary. It is carried.

Chairman C. J. Geyer:—The Committee recommends the withdrawal of track tool plans Nos. 1, 2, 3, 5, 6, 9, 11, 12, 13, 14, 15, 16, 18, and 19 adopted in 1930 and substitution of plans of like numberings herewith submitted.

I move that these new plans herewith submitted be adopted as recommended practice and printed in the Manual.

The President:—It has been moved and seconded to adopt the plans as printed, as I understand, from pages 936 to 947, inclusive.

Chairman C. J. Geyer:—That is right.

The President:—In order to give the members a chance to discuss and amend, I will ask the Chairman to call attention to each particular plan, and if anyone has anything to say they will please stand up and say it at that particular time.

Chairman C. J. Geyer:—Plan No. 1, Clay Pick, dated September, 1929, revised September, 1933.

Plan No. 2, Tamping Pick, dated September, 1929, revised September, 1933.

Plan No. 3, Spike Mauls, dated September, 1929, revised September, 1933.

There is no revision in Plan No. 4, which is the next one following.

Mr. R. P. Winton (Norfolk & Western):—No mention is made of Plan No. 4. I want to call attention to a note which says, "All wrench jaws shall be milled to exact dimensions shown." I take exception to the term "exact." The dictionary definition of exact is "suffering or exhibiting no departure from the letter or standard". Practically, it is impossible to make anything exact. The term is unsuited. What we want to do is to get an opening suitable for a nut. The A.S.A. specifications for nuts permit a tolerance in the size of the nut. We should permit a reasonable tolerance in the size of the opening. If we do not give a tolerance, the manufacturer can use his own judgment in what is his idea of exact, and we may not get what we want at all.

I recommend that this plan be revised and that suitable tolerances be indicated on the drawing. While I am still on the floor, the same thing applies to another plan which is not mentioned for revision and that is Plan No. 20 which shows the Track Gage. There again it says: "No tolerance allowed in gage distance." We want to get our track approximately correct but we certainly cannot get it exact.

In making some of the most accurate machinery, for example, ball bearings, which is about as fine work as is done, we permit a tolerance in the size of the bearings. Certainly nobody will think that a track gage needs to be made as close as a ball bearing.

Therefore, I recommend that this plan be revised and suitable tolerances for a track gage be included on the drawing.

Chairman C. J. Geyer:—For the benefit of the members, and particularly the last speaker, I believe I failed to make it clear that the plan not specifically mentioned here, (you spoke of Plan No. 4), and the other plan, have previously been adopted and printed in the Manual. We are not proposing any change in that plan this year, but the Committee will be glad to take your suggestions under advisement for future revision.

Plan No. 5, Lining Bar, dated September, 1929, revised November, 1933.

Plan No. 6, Rail Tongs, dated September, 1929, revised September, 1933.

Plan No. 9, Spike Puller, dated September, 1929, revised September, 1933.

There, again, we skip two or three plans on which we made no recommendation this year. They are already approved and in the Manual.

Plan No. 11, Claw Bars, dated September, 1932, revised September, 1933.

Plan No. 12, Track Adze, dated September, 1929, revised September, 1933.

Plan No. 13, Double Faced Sledge, dated September, 1929, revised September, 1933.

Plan No. 14, Chisel End Tamping Bar, dated September, 1929, revised September, 1933.

Plan No. 15, Spear End Tamping Bar, dated September, 1929, revised September, 1933.

Plan No. 16, Track Chisel, Design No. 1, dated September, 1929, revised September, 1933. Also Track Chisel, Design No. 2, dated September, 1929, revised September, 1931. There is no revision, I believe, in Design No. 2.

Plan No. 18, Tie Plug Punch, dated September, 1929, revised September, 1933.

Plan No. 19, Round Track Punch, dated September, 1929, revised September, 1933.

I move the adoption of these plans as recommended practice and for publication in the Manual.

The President:—The question is on the revision of the plans as shown on pages 936 to 945, inclusive. Is that correct?

Chairman C. J. Geyer:—That is correct, with the exception of those plans on which we are not making any recommendations this year. For convenience the entire set was published in the Bulletin.

The President:—To make that clear, I understand the plans shown on pages 946 and 947 will be brought up later. Are you ready for the question on the adoption of the plans previously mentioned? Is there any further discussion? All those in favor will vote "aye"; contrary. It is carried.

Chairman C. J. Geyer:—The next subject on Revision of Manual is the revision of the Book of Trackwork Plans. The Trackwork Plans covering Switches, Frogs, Crossings, etc., is one of the most important subjects before the Track Committee and one that is always with us. The last general printing of this portfolio was in 1929, five years ago.

The 1933 issue carries an index supplement of three pages, listing changes on 117 plans. It was the opinion of the Committee that, in order to make this portfolio more convenient, in fact to make it so it could be properly used by the members of the Association, all of these revisions previously approved should be brought up to date, corrections made on the basic plan. The Committee therefore spent most of the past year in making these revisions that had previously been approved and making some more or less minor additions that had not previously been brought before the Association.

The new issue which is now ready contains 176 plans. There are 14 more plans to be temporarily withdrawn until a little further work is done on them, which we think will be ready within a very short time.

The plans and specifications for special trackwork consist of data previously presented, revised, first, to include the revisions listed in the 1933 index supplement, pages 4, 5 and 6; second, to apply throughout for heavy weight rails, particularly 112-lb. RE and 131-lb. RE section, with data and specification to apply also to medium weight rails; third, to eliminate inconsistencies, also to clarify by adding new data and revising old data.

An endeavor has been made to specify on each of these plans just what will be furnished when the plan number, section of rail and detail of joint bar are specified. Unless alternates are provided or selected, the detail that shall be furnished, unless otherwise specified, has been based on what is generally recognized as good practice and is in extensive use. The alternates provided in each case cover what is also considered good practice and reported in use by two or more railroads and invite consideration for special locations and for special conditions.

An endeavor has been made to put the plans into such order that they can be readily kept up to date. The detail and sizes of bolts, for instance, are covered in Section 1402, Appendix A, and referred to but not copied on the plans.

Specifications 1402, if thought necessary later, could be revised without having to revise 100 or more plans. In the same manner, the cross-sections and details that apply throughout for a series of frog plans have been incorporated on one detailed plan so that the minor details could be revised, if found necessary, without having to revise all of the plans in the series.

While it is recognized that it is a convenience to have each of the plans complete in itself in all details, it has been found impractical to keep a series of complete plans up to date except at very great expense. As now arranged, the portfolio can be kept up to date at a reasonable cost, thus avoiding the semi-chaotic condition that has arisen in the past due to the necessity of listing in an index supplement a long list of revisions that always had to be referred to in order to intelligently make use of any of the plans.

The frog plans for heavy rails have been revised for uniform 19-½ in. tie spacing throughout, to apply for both heavy and medium weight rails. The lengths given have been specifically designed to suit 112-lb. RE and 131-lb. RE rails for 6-hole joint bars, and notes are given for alternate lengths that may apply for 4-hole joint bars and for medium weight rail.

The 19-½ in. tie spacing was adopted a number of years ago as a compromise to suit guard rails manufactured for fixed tie spacing, such as the manganese-one-piece-6-tie design, Plan No. 510. Any change in this tie spacing for frogs for replacements would result in a misfit of many thousands of guard rails now in use that have a long probable future life.

The specifications in Appendix A have been brought up to date and the material section enlarged to include data compiled from the American Standards Association. Specification E10-1929 will be found more fully outlined in Section 50, Appendix A.

As a list of necessary revisions made for consistency and to bring the plans and specifications up to date would be not only voluminous but very complicated, no attempt has been made to tabulate the revisions individually. A careful record of the plans and specifications before revision, with work sheets and correspondence relating to revisions has been kept for future reference.

The office of Mr. Fritch, Secretary, at 59 East Van Buren Street, has arranged to carry in stock new portfolios and also a supply of complete fillers to fit readily into the old looseleaf cover. These plans are now ready.

I move the adoption of the portfolio of trackwork plans as recommended practice.

The President:—It has been moved and seconded to adopt the portfolio of track-

work plans. This procedure is a little bit out of the ordinary in that it was practically impossible to submit all these plans to all the membership. The books are available, and the Committee, as I understand it, have made no very drastic changes in these plans. The changes that have been made and approved during the past years have been incorporated, and they are now asking for their approval.

Chairman C. J. Geyer:—That is correct. The only minor revisions that have now appeared have not previously been submitted.

The President:—With the assurance of the Chairman that there are only minor revisions included in these plans, the Chair will entertain that motion to adopt them, unless there is objection thereto. Do I hear any objection? The matter is then open for discussion? Are you ready for the question? All those in favor will please say "aye"; contrary. It is carried.

Chairman C. J. Geyer:—The next subject is Appendix B, Specifications for Soft Steel Track Spikes. The Chairman of the Sub-Committee, Mr. Swift, will present the report.

Mr. E. D. Swift (Belt):—The report of the Sub-Committee appears as Appendix B, pages 927 and 929, Bulletin 364.

The Committee offers the following additional sections for inclusion in the Specifications for Soft Steel Cut Track Spikes, now appearing in the Manual at page 252.

"Tension Tests.—(a) The manufacturer may, at his option, substitute tension tests for the chemical analysis specified in Section 2, in which case the finished spikes shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	55,000
Yield point, lb. per sq. in.	0.5 tensile strength
Elongation in 2 in., per cent	25

"(b) When this option is exercised, one tension test shall be made from each 10-ton or fraction thereof.

"Copper Content.—When copper is specified, the percentage contained in the steel shall be not less than 0.20 of 1 per cent."

This matter is offered for inclusion in the Manual as additional matter to the present Specifications for Soft Steel Track Spikes. I move accordingly.

The President:—It has been moved and seconded to include this subject-matter of tension tests and copper content in the specifications for spikes. Is there any discussion on the subject? In that respect I will say that the present Manual just includes a chemical content. Are you ready for the question? All those in favor will say "aye"; contrary. It is carried and so ordered.

Mr. E. D. Swift:—The Committee presents plans for 9/16 in. and ⅝ in. spikes with raised throat as information and for criticism pending their proposed later re-submission as recommended practice.

The President:—It will be so received.

Mr. E. D. Swift:—The Committee offers as information and for criticism pending its proposed re-submission as recommended practice a proposed revision of the specifications now appearing in the Manual for Malleable Iron Tie Plates to consist of substituting the following requirements on tensile strength for the requirements now stated in the specifications:

Tensile strength, lb. per sq. in.	53,000
Elongation in 2 in. per cent	18
Yield point, lb. per sq. in.	35,000

I might add that these requirements are considerably in excess of those stated in the present specifications but are in accord with present malleable iron practices.

The President:—It will be so received.

Chairman C. J. Geyer:—Appendix C, String lining of curves by the chord method and preparation of tables suitable for the use of trackmen. The Committee reports progress this year. Additional information does not justify a report.

Appendix D, Plans and Specifications for Track Tools, will be presented by the Chairman of the Sub-Committee, Mr. Roller.

Mr. W. L. Roller (Chesapeake & Ohio):—You will find the report of this Sub-Committee on page 930, Appendix D, Plans and Specifications for Track Tools.

In the Proceedings, Vol. 31, 1930, pages 555 to 587 inclusive, the Committee submitted the following as information and for further study:

1. General Specifications for Track Tools.
2. Specifications for Hickory Handles for Track Tools.
3. Plans and Specifications for Track Shovels.
4. Plans and Specifications for Ballast Forks.

Since that time, the Committee in collaboration with the various tool manufacturers, have revised and simplified the specifications and have brought the track shovel and ballast fork plans up to date in the light of criticism of the former plans, until we now feel that we have some definite recommendations to make, and we are recommending for adoption the following, under six items found on page 930:

(1) A.R.E.A. General Specifications for Track Tools, Plans A, B, C-1 and C-2, beginning on page 931 and continuing on pages 932 and 933. At the bottom of page 931 you will find the index under Plan A, on 932 the General Specifications for Track Tools, followed by inspection and physical tests. These specifications are not only general but are specific for each and every tool.

I move the adoption of Item No. 1, General Specifications, as covered by these plans.

The President:—You have heard the motion. Is there any discussion? All those in favor will say "aye"; contrary. It is carried.

Mr. W. L. Roller:—(2) A.R.E.A. Specifications for Hickory Handles for Track Tools, Plans D-1, D-2 and D-3, as found on pages 933 and 934.

These specifications have been before you for a number of years and we are now submitting them for adoption as recommended practice. I so move.

The President:—You have heard the motion. Is there any discussion on these specifications? All those in favor will please say "aye"; contrary. It is carried.

Mr. W. L. Roller:—(3) A.R.E.A. Specifications for Track Shovels, Plan E, found on page 935. I move the adoption of this plan and the accompanying specifications.

The President:—The Chair is confused. Are you moving the adoption of the specification and plan as shown on page 935?

Mr. W. L. Roller:—I am moving the adoption at this time of the plan itself.

The President:—It has been moved that we adopt the specification for Plan E on page 935.

Mr. W. L. Roller:—I stand corrected.

Mr. G. R. Westcott (Missouri Pacific):—I do not know whether or not most of the roads are buying shovels on A.R.E.A. specifications. I know one road that is and is having a lot of trouble. We are not using the specification that is outlined here, but if we did I suspect we might have even more trouble than we are having. I refer particularly to the paragraph covering the test. I believe this has been changed from the preceding shovel specifications of the A.R.E.A. I do not believe that the test as outlined here will develop a difficulty that has seemed very common in shovels that we have bought, that is, the failure of the shovel in the weld.

It seems to me as a general proposition that, if the A.R.E.A. specifications are to be adopted, they must be complete enough so that when materials are purchased under

them, the materials will be satisfactory. I do not believe that the test outlined here, as I said a moment ago, will determine the life of a shovel, especially in the strength of the weld if it is a welded strap shovel. I further think that the old specification, while probably better than what is shown here, would not do that.

I would suggest for the consideration of the Committee that they endeavor to develop some sort of a flexure test that will put the shovel on its merit, somewhat as the trackman does, especially when he uses it for nipping a tie.

Incidentally I want to have something to say about the handle for the shovel which is coming up a little later.

Mr. W. L. Roller:—In regard to the test which is set forth in this specification, it was considered by the Committee that this approximated the actual field test very closely and would give a fair and impartial test of the shovel itself. It may not be rigorous enough to meet the specification of the last speaker, but we would be glad to take that suggestion under advisement and consider it for future work.

The President:—Are you ready for the question? All in favor of adopting the specifications for track shovels, Plan E, say "aye"; contrary. It is carried.

Mr. W. L. Roller:—(4) A.R.E.A. Specifications for Ballast Forks, Plan F. This specification is found on page 935. I move its adoption.

The President:—It is moved and seconded that we adopt the Specifications for Ballast Forks, marked Plan F on page 935. Is there any discussion? All those in favor will say "aye"; contrary. It is carried.

Mr. W. L. Roller:—(5) A.R.E.A. Plan No. 21 dated Sept. 1933, Track Shovel, found on page 946. I move the adoption of this plan.

The President:—It has been moved and seconded to adopt the plan for track shovels shown on page 946. Is there any discussion?

Mr. G. R. Westcott:—Just one little item in this plan that from experience I have found troublesome, and that is the shape of the handle or D, so-called. The dimension of 4-in. across the D is good. The manufacturers usually like to make it less than that, and it is pretty hard to get them to come to 4-in. But to make the plan complete we ought also to show the distance from the spool to the top of the handle. They have a tendency also to reduce that dimension. I have noticed some recently that were less than 2-in., and I think that by all reasonable considerations it ought to be 2-½ to 2-¾-in.

Mr. W. L. Roller:—I might say in regard to that criticism of the plan, that matter was taken under consideration by the Committee, and the dimension was omitted on purpose because of the fact that we sought to make a uniform handle for both ballast forks and shovels with a split handle and with the metal D.

Mr. G. R. Westcott:—I see no objection to specifying that dimension for both the shovel and the fork. As a matter of fact, I think it should be specified. Certainly we should give a good-sized man a chance for his fingers when we make a shovel handle for him to use. I believe that dimension ought to be shown.

Mr. W. L. Roller:—I will be glad to accept that suggestion and give it consideration in our future work.

The President:—Are you ready for the question? All those in favor of the motion to adopt the plan for shovels as recommended practice and for inclusion in the Manual will say "aye"; contrary. It is carried.

Mr. W. L. Roller:—(6) A.R.E.A. Plan No. 22, dated September 1933, Ballast Fork, found on page 947. This plan provides for two types of fork, the 10-tine and the 14-tine, providing for two individual widths of the 10-tine fork. This was so designed to meet the comments and criticism from various railroad users. I move the adoption of this plan.

The President:—Is there any discussion? All those in favor of adopting the plan for ballast forks will say "aye"; contrary. It is carried.

Mr. W. L. Roller:—The Committee wishes to submit the following correction to report of 1930 Proceedings, Vol. 31, page 587 in Conclusions: "Plan 21 dated September 1929, A.R.E.A. Wooden Track Tool Handles," should be revised to read "Plan 25, dated September 1929, A.R.E.A. Track Tool Handles."

I move that this correction be made.

The President:—The correction will be made unless there is objection thereto.

Mr. W. L. Roller:—The Committee is offering for study, criticism and for any helpful suggestions that may come, a design of Frog and Crossing Limit Gage for use in maintenance in accordance with Plan 790 adopted in 1933, as a result of study made of Standard Wheel Flanges, Treads and Gages. The design (Plan 31) as submitted is to be used only at crossings and frogs to show proper gages for the use of chilled car wheels and heavy engine drivers.

You will find that plan on the page opposite 930, which gives two separate types, one with cast aluminum ends and one with cast steel ends. Along with this plan we are submitting Plans A and B, A on the next page and B on the reverse side, showing the relation of new and worn wheel equipment and the use of this gage.

Some of these gages have been made and put into practical use, and they are found to be very helpful as a guide as to when the flangeway should be ground out to provide for the chilled car wheels. This plan and the instructions beginning at the bottom of page 930 are offered to you for information and further study.

The President:—It is so received.

Mr. W. L. Roller:—The Committee requests that the subject be continued and that a study of additional tools be made, particularly for use in the laying and handling of heavier rails.

Chairman C. J. Geyer:—Appendix E, Plans for Switches, Frogs, Crossings, Slip Switches. In the absence of the Chairman, Mr. Caruthers will submit the report.

Mr. E. W. Caruthers (Pennsylvania):—The report of the Sub-Committee is found on page 948, Bulletin 364.

The Committee presents for adoption as recommended practice Plan 505, which written plan consists of Specifications for Adjustable Guard Rail Clamps. Guard rail clamps are now in use on a number of large railroad systems, and this plan was prepared to enable railroads to obtain guard rail clamps of a more suitable and uniform design.

This plan was prepared in conference with the Standardization Committee of the Manganese Track Society.

The Committee recommends that Plan 505, A.R.E.A. Specifications for Adjustable Guard Rail Clamps, included in the revised Portfolio of Trackwork Plans, be adopted as recommended practice and printed in the Manual. I so move.

The President:—That is more a specification than a plan. It will not take long to read it, and it should be submitted to the convention. I will ask the Chairman to read it before we vote on it.

Mr. E. W. Caruthers:—"A.R.E.A. Specifications for Adjustable Guard Rail Clamps:

"(1) Clamps shall be so designed that they can be readily applied, and shall have a fit that provides a bearing against the web and under the head of both the running rail and the guard rail.

"(2) Clamps shall provide an adjustment in the width of the flangeway of at least ½", in increments not greater than ⅛", when used with unworn rails, the width of the flangeway shall range from 1-⅝" to 2-⅛", however, the adjustment may be enlarged, but it must be possible to obtain 1-⅝" and 2-⅛" flangeways.

"(3) Clamp yokes shall be of rolled, forged or cast steel, and shall extend above the normal position of base of rail not less than 4-⅜" for rails over 6" high, 3-¾" for rails 6" high and under but over 5" high, and 3-⅜" for rails 5" high and under.

"(4) Clamp yokes shall be capable of sustaining a load of 60,000 lb. without taking a permanent set of more than 0.02 in. across the jaw opening, the measurement to be taken between points marked on the normal top surface, they shall not fracture under a load of less than 90,000 lb. The load shall be applied through pivot pins at points not less than 3-½" above the normal position of base of rail for rails over 6" high, 3" for rails 6" high and under but over 5" high, and 2" for rails 5" high and under.

"(5) Separator blocks shall be of cast steel, cast iron or malleable iron, interlocking both vertically and horizontally, with suitable means for adjustment, and shall be so designed that they will maintain the proper position with respect to the yoke. Separator blocks and any other parts functioning against running rail or guard rail shall be of heavy design, with ample bearings against rails.

"(6) Adjusting wedges shall be of forged or cast steel or malleable iron, and suitable means shall be provided for holding them in position after they are driven tight.

"(7) For location for clamps, see data on Plans No. 503 and 504 covering details for tee-rail guard rails."

The President:—Is there any discussion? All those in favor will say "aye"; contrary. It is carried.

Chairman C. J. Geyer:—The next report, Appendix F, is only one of progress. That Sub-Committee confined all its work this year to revision of the Manual, which has been previously handled.

Appendix G, on Corrosion of Rail and Fastenings in Tunnels, the Committee reports progress.

Appendix H, Gage of Track and Elevation of Curves with Reference to the Use of Roller Bearings on Railroad Equipment. This is recommended as a final report this year, and I will ask the Chairman of the Sub-Committee, Mr. Breed, to present the report.

Mr. C. W. Breed (Burlington):—The elevation of curves must be governed primarily by the speed of trains passing over them. If the use of roller bearings because of mechanical construction were a controlling factor of the speed of trains in which they might be used, to that extent might they be an element in selecting the proper elevations of curves over which the train passed.

In order to obtain accurate information relative to the possible limits in the use of roller bearings on curves at any desired speed of operation, letters of inquiry were addressed to the large manufacturers of roller bearings, which elicited the following replies."

These replies all agree with the conclusion on page 950.

"Conclusion.—There is no different problem in the selection of the proper elevation for curves over which it is desired to operate railway equipment using roller bearings than is present if equipment is supplied with ordinary bearings."

The Mechanical Division of the A.R.A. concurred in this conclusion, and the report is submitted as information.

The President:—The report will be received as such.

Chairman C. J. Geyer:—The next report is Appendix I, Effect of Existing Materials in Track on Design of Tie Plates and Punching Thereof, together with Interrelation of Slotting of Joint Bars and Size of Track Spikes, and Appendix I-1, Design of Tie Plates for R.E. Rail Sections. This report on design of tie plates is being made for inclusion in the Manual. Mr. Macomb, Chairman of the Sub-Committee, will present the report.

Mr. J. de N. Macomb (Inland Steel):– Appendix I-1 is on page 950.

At the meeting of the Track Committee on September 21, 1933, the subject "Plans for Standard Tie Plates" was assigned.

Standard drawings of most of the larger railroads represented in the Association covering track materials were available to the Sub-Committee. From these standard drawings tabulations were prepared, showing the characteristics of the tie plates in use by these railroads with rails of various weights and sections. Studies were made of these tabulations, keeping in mind the trend toward more sturdy construction in railroad track, as a result of which the tie plate plans shown in Fig. 2 to 8, inclusive, were prepared, their principal characteristics and uses being summarized in Fig. 1.

Since the February Bulletin was issued, a meeting of the Committee was held on February 28, and certain corrections and revisions of the plans as published in the Bulletin were made.

On Fig. 1 enter at the foot of the sheet the following notes: "All A.R.E.A. Standard Tie Plates to be 7-½ in. wide." That simply gives the practice shown on the drawings. They are all 7-½ in. wide. "All A.R.E.A. Standard Tie Plates to be canted approximately 1 in 40." That also gives the practice shown on the drawings.

Then follows Note 1 at the foot of page 950 and following that Note 2. Those notes will be read in a moment. Fig. 2, 3, 4, 6 and 7, which are tie plate drawings having inclined ends, have reference marks in error. Those should be removed.

On Fig. 5 the lower outer corners of the section are to be inclined and rounded as is done in Fig. 8.

In Fig. 2, 3, 4, 6 and 7, the depth of the ribs in the anchor bottom design are shown as 3/16 in. They are reduced to 5/32 in.

Fig. 4, 5, 7 and 8, which are double shoulder tie plates, carry the following notation: "A variation of 1/16 in. over and nothing under will be permitted in the distance between shoulders."

In Fig. 2, 3, 4, 6 and 7, which are designs with inclined ends, the thicknesses of the plates with rolled crown are 1/32 in. greater at the center than the thickness of the corresponding tie plate with no camber or pressed camber.

It is thought that where the design with rolled crown is 1/32 in. thicker than the design of a section uniform across, the two sections will correspond in weight and strength better than as shown in the drawings.

Fig. 5, which is shown only as a rolled crown section, is 27/32 in. thick at the high shoulder.

Fig. 8, which is also a rolled crown section is 1 in. thick at the high shoulder, the end portions which are of uniform thickness are 11/16 in. thick.

Fig. 1 to 8, revised as just noted, together with the two notes, 1 and 2, are presented for adoption as recommended practice and printed in the Manual.

"Note 1.—Where a railroad's existing Standard Tie Plate is canted approximately 1 in 20, or has no cant (flat), A.R.E.A. standard design may be modified to correspond therewith, for use with rails having the same base width.

"Note 2.—Where existing standard spacing of spike holes, parallel to shoulder of tie plate, used with same width of rail base by any railroad, is not in accordance with A.R.E.A. standard, such existing spacing may be substituted."

I move that Fig. 1 to 8 inclusive be adopted and printed in the Manual.

The President:—You have heard the motion, gentlemen. Is there any discussion on these plans?

Mr. J. de N. Macomb:—These plans as they have been drawn have been presented to Dr. A. N. Talbot. I think he has some notes on the subject, and I hope we may hear from him.

Dr. A. N. Talbot (University of Illinois):—Although the Sub-Committee very kindly invited me to one of their meetings, I was unfortunately not able to attend, and so I do

not know what was put forward in the discussion as the purpose of certain dimensions and certain parts of the design in the tie plates recommended. I do not wish here to enter into any detailed criticism of these tie plates, but I have prepared some notes that may have a bearing upon the design of tie plates and that will help in making calculations and comparisons.

I have put down several topics, as follows:

1. The principal purpose of the tie plate, the distribution of load on the tie over the area of the tie plate at moderate intensities.
2. The bearing of the rail base on the tie plate longitudinally of the rail and the relation between this bearing and the flexure of the rail with any tilting of the tie plate and tie.
3. Strength and stiffness and length of tie plate and corresponding effect on the stresses in rail flange.
4. Bearing of tie plate on tie.
5. Bearing of rail base laterally on the tie plate.

1. **Purpose of the Tie Plate.**—It is obvious, of course, that the principal purpose of the tie plate is the distribution of load on the tie over the area of the tie plate with moderate intensities and without great variations for any load that may be applied through the rail. The amount and direction of the lateral loads or forces are quite variable. It should be kept in mind that the lateral forces on the rail act sometimes inwardly and sometimes outwardly of the track, almost as large inwardly as outwardly. Consequently sometimes there are high pressures at the outside end of the tie plate and sometimes at the inside end. The condition of the tie and the tamping also affect the direction and magnitude of the tie reaction.

A proper length of plate, then, is essential to keep down the extremes of pressure. It is best, of course, to have some eccentricity in the tie plate in such way as to cause the gage to tighten rather than widen. With the eccentricity of the tie plate in ordinary use, even a vertical force on the rail will give greater pressure on the inside end of the plate and thus tend to tighten the gage. From my own studies it has seemed that ¼ in. would be sufficient eccentricity for the purposes of straight track and moderate curves, but the ½ in. given may not be troublesome and will have advantages on the sharper curves.

The purpose, then, should be to make a length sufficiently great to give a proper distribution, with not too large a pressure on the tie at either end of the tie plate, whether the lateral forces act inwardly or outwardly at any time.

2. **The Bearing of the Rail Base on the Tie Plate Longitudinally of the Rail.**—This seems to refer to the flexure of the rail as related to the tie plate and to any tilting of the plate and tie—to the bending of the rail longitudinally. I take it that with all of the ordinary widths of plate and with the heavier rails now in use, the bending of the rail under load itself has little to do with the form needed for the surface of the plate longitudinally of the rail. There is not enough flexure in the rail to affect the form of the bearing materially. If adzing of the tie or its tamping puts the plate out of plane with the base of rail, a crown or camber will relieve small inaccuracies and the resulting bearing will fall not far from the center of the tie.

Such out-of-planeness, I judge, is the principal reason for providing a camber. It would seem that a very slight camber would be sufficient for this purpose. It is certain, however, that a camber does put into the plate unconsidered stresses and renders the plate inefficient as a beam, so that the average thickness across the width would need to be greater than for a flat plate. A flat surface that gives full rail bearing all the way

across the plate has advantages over a cambered plate, and the stiffer the substructure (tie, ballast, and so forth) the less the need for the crown or camber and the greater its disadvantages. Without having heard the advantages claimed for a cambered plate I should prefer the flat plate, especially if the ties are properly adzed to the same plane for both rails.

3. **Strength and Stiffness and Length of Tie Plate, and Corresponding Effect on Stresses in the Rail Flange.**—Will the reaction pressures from the tie plate tend to break out the flange in a crescent shaped break? It has been said that making a longer tie plate adds considerably to the breaking stresses in the flange of the rail. From what calculations and study I have been able to make on this, I am not convinced that the length of the part of the plate beyond the rail has any marked effect on the stresses developed in the rail flange for the lengths of plate in ordinary use, or even somewhat greater lengths.

Analysis indicates that with a perfectly flat plate and flat rail base (meaning flat in a direction longitudinally of the tie) the main bearings of the rail flange, when the rail is loaded, are confined principally to two narrow areas lying just within the two edges of the base. There would be relatively little pressure on the plate, probably none, at the middle of the width of the rail.

From the analyses made with a given plate (see the discussion of the report of the Committee on Stresses in Railroad Track), it was found that the resultants of the pressure between plate and rail base lie about ½ in. inside of either edge of the base and that there is no reaction over the middle portion. It is true, of course, that the surfaces of the rail base and the plate will have imperfections and that these surfaces will vary sometimes one way and sometimes the other, but a position ½ in. inside the edge seems to be a proper place to locate the reactions for calculating the stresses that may come in the flange of the rail and to find whether it has sufficient strength.

With a longer length of plate, quite a long length, the resultant will be a little nearer the edge of the plate than ½ in., but the magnitude of the upward reaction will not change much and so the stresses in the flange of the rail will not vary greatly.

The thickness of the plate, of course, should be great enough to keep the deflection of the plate within reasonable limits. I do not see that the stresses in the rail flange will be affected very greatly by the usual range in the dimensions of the plate itself.

One other thing in regard to these crescent shaped breaks—after hearing a great deal about them I have come to the belief that the breakage of rail flanges results from high loads on certain ties with the applied load force directed in such a way that almost all the load is carried on or near one edge of the base of rail, or that the condition of the ties and their bearings are such that most of the tie reaction necessarily passes through this point. Under the first condition there may then be such a large lateral force combined with an undue vertical load on one or more ties that the load applied is large and has a large sidewise component, just as though the rail were tilted; or under a second condition that would produce the same effect, the position of the tie plate and tie is such that one edge of the rail receives practically all of the tie reaction—that is, the trouble comes from a condition of the track or the loading and not by reason of the design of the tie plate except as the tie plate is too small.

4. **Bearing of the Tie Plate on Tie.**—On the general question of tie bearing, I am a believer in the advantages attained by spending effort and money too in adzing the tie in such a way as to get the bearing surfaces of the ties for the two rails accurately in the same plane.

I also think that spiking the tie plate effectively to the tie has great advantages from a maintenance and economical viewpoint. More nearly perfect bearings on the tie, less mechanical wear, greatly improved and more uniform rail support will be effected.

I think, too, that anchor ribs have objectionable features. With the rib construction the plate will not fully seat on the tie and the bearing will not be uniform over the whole area of the tie plate. The detrusion of the metal into the wood makes opportunity for breaking the fibers and starting decay. With the added friction between flange and tie plate secured by spiking the tie plate closely to the tie and the lateral holding power of the spikes, lateral resistance is provided so that it will not be necessary, I think, to give further anchorage.

5. **Bearing of the Rail Base Laterally on the Tie Plate.**—The bearing between the metal surfaces of the rail and tie plate transversely of the rail will not be perfect and the tolerances used would seem to be comparatively large—that is to be expected. A convex surface in either rail base or tie plate will allow rocking of the rail laterally. No one has advocated a concave surface in either rail or plate, though that would insure definite bearing. A wood plate or shim between the base of the rail and the tie plate seems to have advantages.

Dr. von Schrenk reports that the use of compressed wood plates, where tried out in this country, has proven practical and effective. I think you will agree that this arrangement, if it is practical, will overcome unevenness of the metal surfaces that are bound to be uneven and will give adjustment for some out-of-planeness of tie and rail bearings—and there is a great deal of out-of-planeness at the present time and a little of it makes an increase in rail stresses and distortions. The improved bearing will decrease the stress in rail flanges because of bringing the resultant of the reaction farther in from the edge of the rail. It obviates need for crown or camber. Even if the elasticity of the wood proves not to be available for a cushioning effect, the wood does give an adjusting medium there.

The presence of double shoulders on the tie plates, which should preferably be used with the wood plates, gives other advantages to the track. It should not be overlooked in this respect that high lateral forces act on the rail inwardly of the track as well as outwardly, and if the rail is held closely to place when the pull is inward, by means of the shoulders, a decrease in the lateral force applied to the other rail will result and the side thrust will be divided more evenly between the two rails.

It would seem well, then, to try out the wooden plates more extensively and to evaluate their advantages.

Finally, let me express the view that there are other features in track that contribute to the need for large, heavy tie plates. One is the presence of seasoning checks and shakes and cracks in the tie. It is surprising to see to what extent the ordinary checks increase the deflection and depression of the plate into the wood and produce irregularity in bearing resistance at different parts of the plate. As these checks can hardly be avoided, the alternative is to provide adequate bearing area in the tie plate and sufficient thickness.

Mr. L. W. Skov (Burlington):—In 1932 the Burlington Railroad had a number of rail base failures. This caused an order to be given to investigate our tie plate designs to determine if they in any way were the cause of the failures.

Quite extensive tests were made on several types of tie plates resting on various kinds of timber. The tests were run at our Aurora laboratories. Inspections were also made of tracks to see how the plates behaved in actual service.

The main object of the tests was to determine the effect, if any, the tie plates had on the transverse stresses in the rail base. In order to determine these effects it was

necessary, first, to make a determination of the modulus of elasticity of various kinds of wood used in ties. Next the deflections of the rail base, tie plate and tie were determined, at right angles, to the rail web.

I have listened to Dr. Talbot's discussion, and agree fully with what he has said; however, there are one or two things I would like to add.

The tie plates that we tested were all 7-½ by ½-inch plates. They were of various bottom designs and the plates varied some in thickness. One hundred pound rail was used throughout the entire test. I agree with Dr. Talbot's statement about the transverse stress produced in the rail bases. He did not tie it down to a definite figure but permitted some variation.

Stresses from 30,000 to 38,000 lb. per sq. in. were produced in the rail base at right angles to the web, when the tie plates rested on white oak ties. Other hardwoods having the same modulus of elasticity perpendicular to the grain will produce like stresses in the tie plate and rail base.

While stresses of the above magnitude are within the strength of the steel in the rails, they are not the only stresses present in actual service, and when combined with such other stresses, the resultant might well stress the steel beyond safe limits.

High transverse stresses in the rail base are objectionable on account of the tendency for seams, however small, along the center line of the rail base.

A number of rails were sent to the laboratory and there loaded until base failure occurred. A number of these rails had longitudinal cracks along the center of the web, ranging in depth from 1/16 in. to 1 in.

They always occurred over the tie plate, and they always occurred where the rail showed bearing marks along the edges only. In other words, the rails showed progressive failure where the base received most of the load near its edges.

While the stresses that we found are no higher than the steel should be able to withstand, we have been wondering if, in the cases where the rail does not have full bearing on the tie plate, under the lighter loads, there is a tendency for this often repeated high stress along with the unavoidable seams along the center of the web to produce rail base failure.

In order to determine this, I am satisfied that more study would have to be given to the subject than we could give and did give, but it did occur to me, from the rails investigated, that there is something worth investigating.

Referring to the tie plates, the tests were made in two ways. First, the plates were placed on the ties and loaded. In the second set of tests the plates were bedded on a thin layer of plaster of paris, in order to secure a uniform bearing throughout similar to a fully seated condition. It was realized that in track there are many conditions that are not perfect, but in order to make a test that would permit of proper evaluation it, of course, was necessary to make it as nearly perfect as possible.

With transverse stresses in the rail base of from 30,000 to 38,000 lb., the edge of the rail would deflect upward about 0.004 in., the edge of the tie plate would deflect upward from about 0.028 to about 0.05 in., depending on the type of the plate and on the kind of wood in the tie. In oak ties the timber at or near the center of the rail would be loaded to about 620 to 630 lb. per sq. in., whereas at the edge of the tie would be loaded to less than 300 lb. per sq. in. In the softwood ties such as pine and fir, the condition is somewhat reversed, because the strength of that type of wood, transverse to the grain, is less than 300 lb. per sq. in. If the stress is over that, it is beyond the elastic limit. Fortunately, lumber possesses the same properties as does steel. It can be overstressed a number of times and actually gets stronger. I do not believe that information as to this

property has been published yet, but a good deal of work has been done on it at Madison in the Forest Products Laboratory, and their work seems to bear out our findings.

In view of the high tie stresses, it seems advisable to have the metal so proportioned as to give the most uniform tie loading possible. This can best be accomplished by making the plate as wide as possible, this form of plate also reducing the rail base stress to a minimum.

The President:—Is there any further discussion on this subject of tie plates?

Mr. W. J. Burton (Missouri Pacific):—I understood Major Macomb to say that these recommended tie plates are compromises, or averages, which have been derived from present practice. It seems to me that this is the wrong way to go about a subject of this kind. Certainly, if we do nothing but recommend what we have been doing, we will have no progress.

I listened to what Dr. Talbot said and to what the previous speaker has said, and I am very certain that we have a good deal to learn yet, and there is a good deal of room for improvement in our tie plate design.

I am particularly interested, from the standpoint of the tie, in the shape of the bottom of the plate. I have in mind the work which the Stresses in Track Committee has done in pointing out the undesirable characteristics of tie plates which are not flat but which require varying amounts of traffic to seat, and the undesirable effect of having one tie plate fully seated, and the one on the next tie not fully seated, causing a variation in the support of the rail from tie to tie. One tie will be soft; the plate will sink into that tie, perhaps, under the passage of the first train. The next tie may be hard, and it may take considerable traffic before it is seated, or, it may never be fully seated. One end of the first tie may have a knot running out at the rail seat; the other end may be free of any knot, etc. I am speaking particularly of ties that are pre-adzed, because they are used almost universally now.

This is only one, however, of the several thoughts that come to mind in considering this report of the Committee. I am therefore very hopeful that the Committee will give this subject further study before recommending for inclusion in the Manual.

Putting the present report in the Manual will not improve what we are already doing, because, as Major Macomb has said, the report and the designs are merely compromises, if you please, of present practice. As I see it no great loss will result from holding it over another year and giving further study to the subject.

The President:—Are you ready for the question?

Mr. L. W. Skov:—I would just like to say one more word that was brought to my attention by the last speaker. In our investigation we also tried to determine how long it took for tie plates to seat. On our main line it appeared that it took about two years. The way it was tested was by placing paper along the track under the tie plates, letting a train go across and then seeing how much the tie plate was bearing at the tie. A good percentage of the tie plates take from one to two years before they are fully seated on the ties. Softwood ties, of course, seat much faster. The ordinary ribs on the bottom of tie plates will require about 30,000 lb. to seat them.

The President:—Are you ready for the question? The motion is to adopt the plans shown in the report, on tie plates. All those in favor will say "aye"; contrary. The "ayes" appear to have it, but the Chair is undecided. I will ask for a division of the vote. Those in favor will please stand; contrary-minded will please stand. The motion is lost.

Mr. John V. Neubert (New York Central):—Mr. Wiltsee, Major Macomb and his Committee have done some very excellent work, they have done some very hard work. I was on that Sub-Committee and I did not vote either way. I do not know what

pressure there is to speed up the design of this tie plate, but what leads me to speak now is I believe there are six members on the Sub-Committee who voted against it. There is a little difference of opinion. You have a big problem here, and the tie plate is a big factor in this problem.

I am glad that this subject is carried over for another year because I think you will come to something that is going to be a little more definite than the tie plate we now have.

Mr. J. de N. Macomb:—Appendix I, page 950, effect of existing materials in track on design of tie plates and punching thereof, together with interrelation of slotting of joint bars, and size of track spikes. That subject has been continued for several years, but the work now being done on tie plates by the Track Committee and on joint bars by the Rail Committee, has made it undesirable to try to press the work at this time, and it is recommended that this subject be discontinued.

The President:—The Outline of Work Committee will consider the recommendation.

Chairman C. J. Geyer:—Appendix J, practicability of using reflex units for switch lamps and targets. This is simply a report of information, following out previous reports on this subject.

Appendix K, selective welding up at joints, instead of welding out of face. This report is submitted as information.

Appendix L, desirable tightness of track joints and effect upon the life of rails and joints of overtight joints; of loose joints. This report is submitted as information with the recommendation that the subject be discontinued.

The President:—The Outline of Work Committee will give consideration to that.

Chairman C. J. Geyer:—Appendix M, reclamation of serviceable materials from scrap and retired maintenance of way and structure machines, tools and appliances. There is no report this year.

Appendix N, methods of reconditioning of rail ends, fastenings, frogs and switches in track. This report is submitted as information. The Committee believes that this assignment is a very important subject and recommends that it be continued.

Appendix O, determination of the limiting relative positions of the abutting rails of fixed and drawspans on bridges and proper tolerances. That is only a progress report for this year.

Appendix P, damage to track and devices due to brine drippings from refrigerator cars. In this report the Committee has collaborated with the Mechanical Division, and the Sub-Committee from that Division joins in this report, giving information as outlined in the report.

"Recommendation.—A higher degree of maintenance of tanks and fittings on existing brine tank equipment and better protection of tracks, bridges and signals against brine drippings. Under existing circumstances, this seems the most economical and practical procedure.

"It is recommended that the subject be dropped, at least until such time as there are developments which would make it worth while to revive this subject."

This is simply a continuation of informative reports published in previous Bulletins.

That completes the Track Committee's report.

The President:—This Committee has done an immense amount of work this year. If you realize the work on the track plans and on the track tools, and the work they have done on the tie plates, which was only started the latter part of the year, it is very evident that they have been very active. I wish to compliment them on the work they have done. We now dismiss them with the thanks of the Association (Applause).

DISCUSSION ON BUILDINGS

(For Report, see pp. 529–559)

(Vice-President John E. Armstrong in the Chair.)

Mr. G. A. Rodman (New Haven):—The report of the Committee on Buildings will be found in Bulletin 361, page 529. We have ten subjects under consideration. On five of these we assembled data but not sufficient material to make a report this year. We recommend the reassignment this year of:

(4) Bus Terminal Buildings. (5) Application of Stainless and Rust-Resisting Metals to Building Construction. (7) Vermin and Rat-proofing in Buildings. (9) Mill type and other heavy wood construction for railway buildings. (10) Study the economic value of various basic and composite materials used in building construction and maintenance.

On (1) Revision of Manual, we will have the report presented by Mr. Wilbur.

Mr. O. G. Wilbur (Baltimore & Ohio):—The recommendations of the Committee pertaining to revisions in the Manual will be found on pages 530 to 540, inclusive, of Bulletin 361.

The Committee recommends that on page 316 of the Manual, under Section 10-A, Concrete Roofing Tile, the text be revised to read as follows:

"The joints of large flat tile shall be pointed where necessary so as to provide a smooth surface for the application of the roofing."

Other revisions recommended concern the specifications for built-up roofing on pages 319 to 327, inclusive, of the Manual, under Section 10-D. They cover specifications for various types of built-up roofing on the several classes of roof structures or decks. These specifications have been revised as to form, and in the eight types involved all have been fully framed so that the eight types are consistent with each other. The matter of flashing is covered more thoroughly in the revised specifications than it is now covered in the Manual.

These revisions have been made in order that the specifications will conform to present-day practice. They have been submitted to various roofing manufacturers and contractors who apply roofing, and the Committee has been advised by both that the specifications as revised are in keeping with good practice.

Since these revisions have been in the hands of the membership since the issuance of the November Bulletin, I shall read only the headings and pause briefly for questions.

The Committee recommends, and I so move, that the changes in the Manual as recommended in Appendix A, beginning on page 530 of Bulletin 361, be approved, and the revised text be substituted for that now appearing in the Manual:

Page 530, Materials. Page 532, Type A-1, Tarred Rag Felt, Pitch and Gravel (or Slag) Over Wood or Pre-Cast Units. Page 533, Type A-2, Tarred Rag Felt, Pitch and Gravel (or Slag) Over Homogeneous Roofs Cast in Place. Page 534, Asphalt Rag Felt, Asphalt and Gravel (or Slag) Over Wood or Pre-Cast Units. Page 535, Type B-2, Asphalt Rag Felt, Asphalt and Gravel (or Slag) Over Homogeneous Roofs Cast in Place. Page 536, Type C-1 (Class 2), Asphalt Impregnated Asbestos Felt and Asphalt (Smooth Surface) Over Wood or Pre-Cast Units. Page 537, Type C-1 (Class 3), Asphalt Saturated Rag Felt, Asphalt Impregnated Asbestos Felt and Asphalt (Smooth Surface) Over Wood or Pre-Cast Units. Page 538, Type C-2 (Class 2), Asphalt Impregnated Asbestos Felt and Asphalt (Smooth Surface) Over Homogeneous Roofs Cast in Place. Page 539, Type C-2 (Class 3), Asphalt Saturated Rag Felt, Asphalt Impregnated Asbestos Felt and Asphalt (Smooth Surface) Over Homogeneous Units Cast in Place.

Vice-President John E. Armstrong:—I understood your motion to include revisions in 10-A and 10-D.

Mr. O. G. Wilbur:—Yes, 10-A and 10-D as indicated in Appendix A.

Mr. W. A. Radspinner (Chesapeake & Ohio):—If you apply for insurance on a building, a representative comes to your property to inspect it and give you an insurance rating. If your building has built-up roofing that does not carry the Underwriters' label, you will probably be penalized on your insurance rates.

Mr. O. G. Wilbur:—There is nothing in the specifications which, as I understand it, will prevent you from being given a rating.

Mr. W. A. Radspinner:—Have they collaborated with the National Board of Underwriters and the Underwriters Laboratories in that respect? These labels are put out by the Underwriters Laboratories, and whenever a manufacturer buys roofing of any kind he pays for that label. The Underwriters label and their specification is one that is generally used by contractors when they buy roofing. The laboratories put out little books periodically listing roofings that carry that label. I do not know for sure about this, but I am pretty certain that if you are building a building and put on a roof, if you do not use Underwriters specifications or roofing carrying the Underwriters' label you have to pay for the difference in your insurance.

Mr. O. G. Wilbur:—It is our understanding that the question of rating only covers the material and not the application of the material.

Vice-President John E. Armstrong:—Is there any further discussion? Are you ready for the question? Those in favor signify by saying "aye"; opposed likewise. The motion is carried.

Chairman G. A. Rodman:—Subject (2), Preparation of Specifications for Railway Buildings, will be presented by Mr. Judd.

Mr. F. R. Judd (Illinois Central):—You will find the report on this subject under Appendix B, pages 540 to 551, Bulletin 361.

The Committee submits for publication in the Manual, Specifications for Electrically Operated Freight or Baggage Elevators. These specifications were presented to the last convention and have been in printed form since a year ago February. The Committee has received no unfavorable comments, and we are therefore offering these specifications for publication in the Manual, and I so move.

Vice-President John E. Armstrong:—Will you read it by general headings?

Mr. F. R. Judd:—The specifications will be found in Bulletin 354 published February, 1933, page 682. The headings are:

1. General. 2. Checking drawings. 3. Laying out work. 4. System. 5. Car platform. 6. Car cover. 7. Car frame. 8. Hatchways and shaft enclosure. 9. Hoisting machine. 10. Overhead sheaves. 11. Lifting cables. 12. Counterweights. 13. Guide posts and guides. 14. Control. 15. Operating device. 16. Buffers. 17. Elevator doors or gates. 18. Governor and safety device. 19. Limit switches. 20. Safety switch. 21. Foundations and supports. 22. Lubricators. 23. Screens and ladders. 24. Electrical equipment. 25. Signal system. 26. Lighting car. 27. Cable lock. 28. Lubricants. 29. Prosecution of work. 30. Cutting. 31. Painting. 32. Instructing operator and railroad. 33. List of parts. 34. Guarantee. 35. Inspection. 36. Final inspection and test. 37. Laws and ordinances. 38. Cleaning. 39. General conditions.

Vice-President John E. Armstrong:—This is a specification which has been before you for a year for consideration. Are you ready for the question?

Mr. J. C. Irwin (Boston & Albany):—Mr. Judd has outlined a few provisions that are distinctly contract provisions. We have repeatedly made the distinction between specifications and contract provisions as defined in the Manual.

I suggest that those few provisions which are not necessary in connection with the specifications, and which are found in contract forms should be eliminated before this is approved for the Manual, to avoid duplication and also probable conflict.

Mr. F. R. Judd:—I would like to bring the matter before the Association that this question was settled a number of years ago. We already have something like thirty specifications in the Manual. The question of these clauses being both in the specification and in the contract was brought up on the floor of this convention, I think, some six or eight years ago, and at that time it was decided that as long as there was no conflict with the contract, they should remain. So the Committee has been consistent throughout in living up to the instructions they received at that time.

If we are going to change that in any one specification we would have to go through the Manual and, to be consistent, take those same clauses out of probably thirty specifications that are already accepted.

I think the decision of this Association at a previous convention should be recognized at this time, and we should probably continue with the present practice.

Mr. J. C. Irwin:—I make no objection, if they in accordance with those already in the Manual. I have not checked them. Yet I thought that Mr. Judd had cited a few which were distinctly contract provisions. My recollection is that the committees have been instructed in the convention and also in their outline of work to avoid the contract provisions. In this case I ask Mr. Judd to mention the last two or three of those and state whether they are contract provisions in the uniform contract forms.

Mr. F. R. Judd:—You mean to read the particular clauses?

Mr. J. C. Irwin:—I mean the headings about inspection.

Mr. F. R. Judd:—Final Inspection and Test. The wording under that does not conflict with the requirements of the contract.

Mr. J. C. Irwin:—I make no further objection if Mr. Judd is satisfied with that. I have not checked it. I simply state the general principle that the contract provisions should be avoided. In this case I would not wish to prevent their going through, but it may be reconsidered in connection with the revisions and the elimination of duplications in the Manual. At the present time I make no further objection.

Vice-President John E. Armstrong:—Is that a matter that might be taken care of by the Manual Committee as they go through that?

Mr. J. C. Irwin:—I think so.

Vice-President John E. Armstrong:—Is there any further discussion? Are you ready for the question? Those in favor signify by saying "aye"; contrary likewise. The motion is carried.

Mr. F. R. Judd:—The Committee further submits at this time the following specifications: Section 30-D, Steel Chimneys—Welded. Section 30-E, Genuine Wrought Iron Chimneys. Section 10-D, Built-up Roofing, Type C-1 (Class 1), and Type C-2 (Class 1). Section 31-A, Wood Screens, and 31-B, Metal Screens.

These specifications are offered as information.

Vice-President John E. Armstrong:—They will be so received.

Chairman G. A. Rodman:—Subject (3), Remodeling Freight Houses for Accommodation of Truck Door-to-Door Delivery of Freight. The report will be presented by Mr. Irwin.

Mr. A. C. Irwin (Portland Cement Association):—I will read the first two paragraphs because they constitute a conclusion made by the Sub-Committee.

"All l.c.l. freight is, to all intents and purposes, a door-to-door delivery, either by individual trucks or trucking companies.

"Existing freight houses usually have tracks on one or both sides for the loading or unloading of freight cars. Generally, on one side is the tailboard space, with or

without platform, for trucks or other vehicles delivering or receiving freight. The same arrangement should meet the requirements of the door-to-door system, consequently it is unnecessary to remodel existing freight houses materially, if any. All that is involved is a change in responsibility and operation."

The recommendation of the Committee is that this subject be discontinued.

Vice-President John E. Armstrong:—The recommendation is that the submission be accepted as information and the subject discontinued. It will be accepted as information and will be discontinued or not, according to the decision of the Committee on Outline of Work.

Chairman G. A. Rodman:—Subject (7), Relative Merits of Wood and Fireproof Roof Structures, which includes Wood, Hollow Tile Fire-proofing, Concrete and Cement Tile, etc. Mr. Upson will present the report.

Mr. A. T. Upson (American Forest Products Industries, Inc.,):—This subject has been before the Committee for two years. During that time a great deal of study has been given the subject in order to bring out all the practical and scientific data available and, at the same time, to present the resulting information in a form that will make it of the greatest use to Building Engineers. That has resulted in the report under Appendix G, on page 552.

You will see that it first takes up and describes very briefly each of the twenty-one different types of materials used singly, or in combination with other materials, for roof decking. It then attempts to rate these twenty-one types of decks from their ten different property standpoints.

We believe that the information as presented will furnish a reliable guide to the Building Engineer in the selection of roof decks for different types of buildings. It is offered as information.

Vice-President John E. Armstrong:—It will be so accepted.

Chairman G. A. Rodman:—Subject (8), Causes of Dust Explosions in Grain Elevators and Methods of Obviating the Hazard. The report will be presented by Mr. Stone.

Mr. A. B. Stone (Norfolk & Western):—The report of the Sub-Committee on Causes of Dust Explosions in Grain Elevators and Methods of Obviating the Hazard is under Appendix H, pages 554 to 559, Bulletin 361.

The conclusions reached by the Committee, as indicated on page 558, are as follows:

"The hazards of dust explosions can be reduced by—

"(1) Good housekeeping to prevent accumulation of static dust.

"(2) Dust-tight electric equipment.

"(3) Plenty of ventilation to prevent atmosphere from becoming charged with explosive dust.

"(4) Dust collection by fan produced suction—to remove dust in suspension at all points where grain is agitated."

The Committee recommends that this report be accepted as information.

Vice-President John E. Armstrong:—If there is no objection, it will be so received.

Chairman G. A. Rodman:—That completes the report of the Buildings Committee.

Vice-President John E. Armstrong:—Gentlemen, as usual, the Buildings Committee has turned out an excellent report. They will be excused with the thanks of the Association (Applause).

Mr. E. E. R. Tratman (Civil Engineer—by letter):—The report of the Sub-Committee on the remodeling of freight houses for accommodation of door-to-door delivery of freight, page 551, says that "all l.c.l. freight is to all intents and purposes door-to-door delivery, either by individual trucks or trucking companies". This does not seem to be

quite correct or to cover the situation, since in railroad parlance "door-to-door service" implies handling from consignor's door to consignee's door by or under direct responsibility of the railroad. Apparently it was this fact that led to the subject being assigned for committee consideration. Whether any remodeling of freight houses would be required or advantageous for "door-to-door" service where the railroad operates (or controls) the service between the "doors" and the freight houses, is not touched upon in the report.

DISCUSSION ON SHOPS AND LOCOMOTIVE TERMINALS

(For Report, see pp. 403–417)

(Vice-President John E. Armstrong in the Chair.)

Mr. J. M. Metcalf (Missouri–Kansas–Texas):—The report of the Committee this year is found in Bulletin 360 beginning on page 403.

The Committee has no recommendations to make for revision of the Manual this year. It reports progress on the following subjects:

(2) Welding Equipment Installations as Applied to Shops and Locomotive Terminals.

(3) General Reclamation Plants.

(7) Car Wheel Shops.

It is making a report on Subject (4) Turntables, which will be presented by Mr. Kimball, Chairman of the Sub-Committee.

Mr. L. P. Kimball (Baltimore & Ohio):—The report of this Sub-Committee will be found in Appendix A, beginning on page 403. This report is a continuation of the report of the same Committee made last year, in which all but one of the recommendations as then presented were accepted by the Association for inclusion in the Manual. This one conclusion, identified as No. 3, was referred back to the Committee for further consideration.

The Committee made a detailed investigation of the general practice of railroads in regard to this subject, which is the method of making connection to the electrical apparatus for operating the turntables, and the results of this investigation are shown in the questionnaire as tabulated on pages 404 and 405. As a result of the information contained in the replies to the questionnaire, the Committee has revised their former Conclusion No. 3 as previously submitted, and recommends that the conclusion as now appearing at the bottom of page 405 be accepted by the Association for inclusion in the Manual. This conclusion reads as follows:

"Where modern locomotives are to be turned, mechanical power for operating turntables should be provided. Where current is available, electricity is the most reliable means of operating a turntable. The power wires may be led to the table, either overhead or underground. In either type care should be taken to see that installation is made so as to minimize the danger of interruption in case of fire, storm, inadequate drainage or other emergency. Where electric power is not available, a compressed air motor may be used."

I move that this conclusion be accepted for publication in the Manual with the other conclusions accepted last year.

Vice-President John E. Armstrong:—You have heard the motion and the second, gentlemen. Is there any discussion? If not, those in favor signify by saying "aye"; opposed likewise. The motion is carried.

Chairman J. M. Metcalf:—On Subject (5), Power Plants, the Committee submits a progress report printed on pages 406 to 409, inclusive and asks that the subject be continued for further study.

Vice-President John E. Armstrong:—It will be so arranged.

Chairman J. M. Metcalf:—On Subject (6), Wheel-Removing Equipment for Engine Houses, the report will be presented by Mr. Hawk, Chairman of the Sub-Committee.

Mr. A. T. Hawk (Rock Island):—The report on Wheel-Removing Equipment for Engine Houses is shown on pages 409 to 414 inclusive. The first part covers the Evolution of Drop Pit Equipment, shown on pages 409 and 410, and a general description of Drop Tables shown on page 411. At the bottom of this page is shown the special points of advantage of drop tables. Page 412 gives the general requirements for drop tables; 413 shows an illustration of a typical layout where three drop tables are used, one for tender truck, one for drivers and trailers and the other for engine trucks. Page 414 shows a typical layout where only one drop pit is used for handling all classes of wheels. The dotted lines indicate what might be done in the way of lengthening the stalls, and a new location for the drop table so that an engine might be entirely enclosed in the engine house when undergoing repairs necessitating removal of wheels.

This report is given as information, and it is asked to have it published in the Proceedings.

Vice-President John E. Armstrong:—It will be so accepted.

Chairman J. M. Metcalf:—The report on Subject (8), Car Paint Shops, will be presented by Mr. Dorland, Chairman of the Sub-Committee.

Mr. A. G. Dorland (Elgin, Joliet & Eastern):—The report of the Sub-Committee on Car Paint Shops is shown as Appendix G, pages 415 to 417.

I wish to call your attention to a correction at the bottom of page 415 in the last line. It should read "twelve and one-half days" instead of "twelve and one-fourth days."

On page 416, in the first paragraph, the capacity of the shop is shown on a percentage basis. The Sub-Committee has been asked to show how we derived the formula for these figures.

Our questionnaires asked for the number of cars in service normally, the number painted annually and the number of days in the shop. The formula was derived as follows: By multiplying the number of cars painted annually by the number of days in the shop, this result to be divided by the product of number of cars in service and 280 (the latter representing the number of days shop is operated annually).

The report is submitted as information, and I suggest that the subject be continued.

Vice-President John E. Armstrong:—It will be so accepted.

Chairman J. M. Metcalf:—That concludes the report.

Vice-President John E. Armstrong:—Although there is very little Manual material in this report this year, there is a mass of concentrated information. In excusing the Committee with the thanks of the Association, I wish to compliment them (Applause).

DISCUSSION ON MAINTENANCE OF WAY WORK EQUIPMENT

(For Report, see pp. 473–520)

(Vice-President John E. Armstrong in the Chair.)

Mr. C. R. Knowles (Illinois Central):—The report of Committee XXVII—Maintenance of Way Work Equipment, appears on page 473 of Bulletin 361.

The Committee reports progress on the following subjects:

(1) Revision of Manual.

(6) Methods of keeping data on work equipment and labor-saving devices.

(7) The selection and training of maintainers and operators of work equipment.

(8) Use of ballast discers.

(9) Organization for the use of tie-tamping machines, air and electric.

(10) Rail laying machines and auxiliary equipment.

(12) Tie adzing, scoring and boring machines.

(14) Prepare manual of instructions for care and operation of maintenance of way work equipment.

(17) Use of oil spraying machines for oiling rails and fastenings, steel structures and roadbed.

The report of Sub-Committee (3) on Track Grinders appears on page 475. Mr. Bowen, Chairman of the Sub-Committee, will present the report.

There is an error on page 473, Subject (2), Standardization of parts and accessories for railway maintenance motor cars. The paragraph carries the recommendation that the report be adopted for publication in the Manual. At the last moment the report was withdrawn, and the Committee merely reports progress.

Mr. M. D. Bowen (Milwaukee):—The subject, Adaptability of Air and Electric Driven Tools in Maintenance of Way Work, perhaps does not cover exactly the work of the Sub-Committee, which was later assigned to them under the heading "Track Grinders". It is a new subject, and, of course, grinding done in connection with rail welding is somewhat newer than rail welding itself.

For that reason there is a good deal of work yet to be done relative to the development of the machine and the carrying out of the work that the machines have to do. Any information contained in the tentative report is submitted more for the information of the railroads doing that type of work than with the thought of being considered a definite report.

Questionnaires were sent out to nearly all of the railroads and to all manufacturers that were at that time known to be manufacturing track grinding machines. Numerous pictures of various machines were published as a matter of information to those interested in track grinding.

The report as submitted contains information available at this time. Numerous developments are now under way, and we expect to report on them in the future as the information develops.

Vice-President John E. Armstrong:—The report will be accepted as information.

Chairman C. R. Knowles:—The report of Sub-Committee (4) on Snow-Melting Devices appears on page 482. This report covers additions to last year's report on the same subject and includes a few changes in that report. The several numbers under the heading of Types and Bibliography tie in with last year's report.

The report is submitted as information.

Vice-President John E. Armstrong:—It will be so accepted.

Chairman C. R. Knowles:—The report of Sub-Committee (5) on Track Type Tractors, with special reference to front end loaders, appears on page 485. Mr. Pittman, Chairman of the Sub-Committee, will present this report.

Mr. T. M. Pittman (Illinois Central):—The report of Sub-Committee (5), Use and Adaptability of Track Type Tractors in Maintenance of Way Work, will be found on pages 485 to 498. This is a continuation of last year's report.

Last year the report gave a general description of track type tractors and some of the interchangeable attachments by which they can be better adapted to special classes of work.

This report gives a more detailed description of two of those attachments, the front end loader on pages 485 to 488, and air compressors on pages 488 to 492.

The remainder of the report shown in Part II gives a suggested scoring sheet for track type tractors. The aim of this sheet is to insure that all makes of tractors being considered will be graded on the same features, which are listed, to avoid their being overlooked. This will result in a more intelligent comparison of the machines. The sheet, however, should be adjusted to fit particular needs or conditions on individual roads. The report is submitted as information with the recommendation that the subject be reassigned and continued for the next year.

Vice-President John E. Armstrong:—The report will be so received.

Chairman C. R. Knowles:—The report of Sub-Committee (11) on Weed Destroying Equipment appears on page 498. This report is a résumé of information available in regard to weed destroying equipment, including hand methods, chemical weed killers, non-poisonous powder, steam weed destroyers, mowing machines, ballast discers and weed burners.

This report is submitted as information.

Vice-President John E. Armstrong:—It will be so accepted.

Chairman C. R. Knowles:—Report of Sub-Committee (13), Track Welding Equipment, appears on page 504. Mr. Trissal, Chairman of the Sub-Committee, will present the report.

Mr. J. M. Trissal (Illinois Central):—In studying this subject your Committee has endeavored to set up certain fundamental differences between oxy-acetylene and arc welding, and to give general information relative to the equipment employed in performing both types of welding. Certain of the facts developed favor oxy-acetylene welding from an economic standpoint, and others favor electric arc welding. Both types of welding can be employed with equal success on track work, except manganese, the welding of which requires the use of the electric arc.

The use of the multiple tip flame in gas welding, with the attendant increase in rate of depositing metal, has been considered.

A comparison is made between the alternating current and direct current type of electric arc welding machine. A further comparison is made between the constant potential and variable potential direct current electric welding equipment. Particular study has been given the method of making portable the variable potential types of electric arc welding equipment, attention being called to several specific methods employed by railroads.

A table showing the voltage drop which may be expected in various lengths of cable, with various currents, is included in the report.

This report is submitted as information.

Vice-President John E. Armstrong:—It will be so accepted.

Chairman C. R. Knowles:—The report of Sub-Committee (15), on the Use and Maintenance of Paint Spraying Equipment, together with Appendix H, Hazards of Spray Painting, appears on page 510.

This report is a continuation of the report previously submitted by the Committee and covers a study of a concrete case of spray painting. The Committee also presents on page 513 a compilation of information available on the hazards of spray painting. This report is submitted as information.

Vice-President John E. Armstrong:—It will be so accepted.

Chairman C. R. Knowles:—Report of Committee (16), Organization for the Use and Maintenance of Ballast Cleaning Machines, appears on page 516. Mr. Elmer, Chairman of the Committee, will present the report.

Mr. William Elmer (Pennsylvania):—Since our report in Vol. 33 of the Proceedings there has been completed and placed in service a two-sided ballast cleaning machine which picks up the dirt and ballast from the intertrack space or border, or both, screening and placing back the clean stone, and disposing of the dirt by means of a belt conveyor across one track and over the shoulder, if working on a fill, or storing the dirt in a large bin constructed over two flat cars, if working in cuts. The dirt can be moved out of the bin and fed to the conveyor when the machine is again working on a fill. The operating expense runs about 3 to 5 cents per foot, and the output is estimated to be in the neighborhood of 100 miles of center ditch cleaned each month.

Another improved machine brought out since our former report is a combination scarifier and blader adapted to work in stone valleys and shoulders. This machine is self-contained and self-propelled on a heavy track motor car and embodies wings which may be lowered on either or both sides by means of a pneumatic hoist, and the ballast can be thrown out and later thrown back, with a considerable portion of the dirt removed, and shaped up against the ends of the ties to approximately correct shoulder section.

This report is submitted as information.

Vice-President John E. Armstrong:—It will be so accepted.

Chairman C. R. Knowles:—That concludes our report.

Vice-President John E. Armstrong:—This report barely indicates the work that this Committee is doing. It is breaking new ground. It is one of our youngest Committees and is breaking ground that should be broken. It is getting results. The Committee is excused with the thanks of the Association (Applause).

Mr. E. E. R. Tratman (Civil Engineer—by letter):—In regard to the welding of rails, the report on track welding, page 504, deals only with the building up of worn rail ends. It might be of interest to supplement this matter with information as to the welding of rail joints to form continuous rails and so reduce the work of maintaining joints. This has been done for tunnels and for wide road crossings, where joint maintenance would be troublesome. The report of the Committee on Grade Crossings, page 564, provides for welding of the latter class. On the New South Wales Government Railways, Australia, the thermit welding of rails has been practiced to eliminate a proportion of the joints, and a total length of equal to 7½ miles of single track has been thus welded. The greatest continuous length is said to be 225 feet, with 11/16-inch joint spaces at the ends. On the South African Government Railways, old 60-lb. rails 21 and 24 feet long, against the present standard length of 40 feet, have been welded into lengths of 63, 69 and 72 feet for use on branch lines. In England, last summer, I was shown some electrically welded rails in main tracks, making lengths of 120 feet with 60-foot rails. The welds and rails were in excellent condition after some years of service, but the work was purely experimental and seems to have been carried no further than the individual experimental joints.

DISCUSSION ON WATERPROOFING RAILWAY STRUCTURES

(For Report, see pp. 699-712)

Mr. J. A. Lahmer (Missouri Pacific):—The report of this Committee consists of two parts, which are shown in Appendix A, page 699, Bulletin 362, on When to Waterproof or Dampproof and Methods to be Used, and Appendix B, Specifications for Membrane Waterproofing. I will ask Mr. Dalstrom, the Chairman of the Sub-Committee, to present that part of the report which is included in Appendix A.

Mr. O. F. Dalstrom (Chicago & Northwestern):—The report of the Sub-Committee on When to Waterproof or Dampproof and Methods to be Used is given in Bulletin 363, on page 699. I will summarize this report briefly. At the bottom of page 699 are two definitions that are important:

"Waterproofing.—The treatment of any material or structure to prevent the entrance or passage of water or other liquid under head.

"Dampproofing.—The treatment of any material or structure to prevent the entrance or passage of water or other liquid not under head."

Proceeding in accordance with these definitions, the Sub-Committee prepared a set of principles, nine in number, governing the use of waterproofing or dampproofing of railway structures. These are shown on page 700 under the heading of "Waterproofing." Seven additional principles, under "Dampproofing", appear on pages 700 and 701. Following this are a number of specific cases, under eleven paragraphs. The specific cases enumerated are:

Abutments, Piers and Retaining Walls.
Single-Span Arches and Box Culverts.
Pedestrian Subways.
Arches—Multiple Span with Spandrel Fill.
Precast Slabs for Bridge Decks and Floors.
Cast-In-Place Concrete Bridge Decks or Floors.
Pump Pits for Subways and Basements.
Pipe Manholes and Pipe Tunnels.
Water Containers.
Walls and Floors of Buildings.
Grain Elevator Pits and Similar Underground Structures.

This report is submitted as information, and comment and criticism are invited.

The President:—It will be so received.

Chairman J. A. Lahmer:—The Specifications for Membrane Waterproofing which begin on page 702 of Bulletin 363 are the same as those that were presented at the convention a year ago, except that they have been passed through the hands of an editing committee to smooth them up and eliminate inconsistencies; they are substantially the same as those of last year excepting for a few minor changes that were made for the clarification or simplification of various requirements.

It is moved that these specifications be accepted as recommended practice and be printed in the Manual in place of specifications on pp. 1171 to 1180, inclusive, of the 1929 Manual.

The President:—You have heard the motion, gentlemen. The subject is now open for discussion. In order to give opportunity for discussion of each article in these specifications, I will ask the Chairman to read them by caption and hesitate a moment to permit discussion.

(Sub-headings of various sections were then read by the Chairman.)

The President:—Is there any discussion on the motion to adopt this specification as recommended practice and for printing in the Manual? All those in favor will say "aye"; contrary-minded. It is carried and so ordered.

Chairman J. A. Lahmer:—That is all.

The President:—This Committee, I feel, has presented a very valuable report which represents a lot of study on the specifications for membrane waterproofing and will be of considerable value to the railroads. They are now dismissed with the thanks of the Association (Applause).

DISCUSSION ON RAIL

(For Report, see pp. 829–878)

Mr. Earl Stimson (Baltimore & Ohio):—We begin the report by a presentation of the rail statistics by Mr. Barnes, Engineer of Tests of this Committee.

Mr. W. C. Barnes (Engineer of Tests, Rail Committee):—The rail failure statistics for 1932 will be found on page 832 of Bulletin 363. These statistics are presented in the usual manner, and I believe they are fully self-explanatory.

I might call particular attention to Fig. 5 on page 836, which shows the rates of failure of rollings from 1927 to 1931 separately by mills. I think this is particularly interesting because the variation in the performance of the different rollings from any one mill is quite pronounced. I think it will be sufficient to move that these rail failure statistics be accepted as information.

The President:—A motion is unnecessary. They will be accepted as information and printed in the Proceedings, unless there is objection thereto. Would anyone like to ask Mr. Barnes any questions on these statistics?

Mr. W. C. Barnes:—Transverse fissure statistics will be found on page 845. These statistics give a cumulative total of failures reported up to December 31, 1932, from all roads. The total number of fissures included in these statistics now amounts to 65,281 fissured rails.

During the last year the service failures, that is, those that actually failed in service, totaled 4,624, and those that were detected and, hence, removed before actual failure totaled 2,430. That seems a very large total, but it is a great deal better than we have had in preceding years.

Exclusive of the detected fissured rails, the failures in 1932 were at the rate of 12.7 per day, which rate, however, has declined from a high of 16 per day in 1929, and indications are that the reduction in number will continue.

Table 3 on page 853 shows a great variation in the fissure record in the rollings of the different mills. These statistics are presented as information.

The President:—They will be received as such. Are there any questions, or is there any discussion on this subject of transverse fissure statistics?

Mr. W. C. Barnes:—On page 854 there is a short summary of the operating results of the A.R.A. rail fissure detector car. On November 14 the car completed its fifth year of operation under the direction of the Rail Committee, having traveled on its own wheels a total of 50,000 miles and tested 23,181 track miles of rail in all sections of the country. Approximately 6,600 track miles were tested during the last year. This work has been done without any interruption whatever, the car having been in rental service continuously except for the short periods necessary for shopping.

Many improvements have been made in methods. The mileage per day has been increased, and the efficiency has also been increased.

The American Railway Association recently approved the purchase of a substantial car to house the detecting equipment, which car is under construction and will be a great improvement, as the other car was rather weak in the knees.

This report is also submitted as information.

The President:—It will be received as such. Are there any questions?

Mr. W. C. Barnes:—The other report I have to present will be found on page 859, tests of alloy and heat treated carbon steel rails. This is simply a compilation of statistics of the purchase of these rails and reports of service tests from various roads that have installed them. During the last one or two years very few of these rails have been purchased on account of conditions, and the statistics are presented simply to keep our record up to date. They are too long to read. They are presented as information.

The President:—They will be so received. Is there any question you would like to ask Mr. Barnes on this subject?

Chairman Earl Stimson:—Subject (4), cause and prevention of rail battering, and Subject (9), heat treating of rail ends to reduce wear, will be found in Appendix F, page 854. The report will be presented by Mr. Graham.

(Mr. F. M. Graham read Appendix F found on page 854 of Bulletin 363.)

Mr. F. M. Graham (Pennsylvania):—The Committee makes the following recommendations:

"In view of the satisfactory experience of heat treating rail ends on the C.M.St.P.&P., C.&O., Erie Railroad, and Pennsylvania Railroad, also considerable experimental testing on several other roads, where results have been most encouraging, it is recommended that the heat treating of rail ends be generally followed in the case of new rail, cropped rail, or where rail batter has not progressed to an objectionable extent.

"It is further recommended in connection with the above that where necessary the top of rail ends be ground to the same height.

"Some of the above-mentioned methods of heat treating rail ends have only been available for a short time, and their relative merits and costs are not now known and should be further studied.

"It is urged that extensive tests by railroads generally of the practice of heat treating rail ends be undertaken and that information including results and costs by various methods be made available."

The President:—While this report is submitted as information, it is a very important subject and a live one at this time. I am sure the Committee will welcome discussion of the subject.

Chairman Earl Stimson:—Further subjects that your Committee considered are economic value of different sizes of rail—again we report progress on this subject; rail lengths in excess of thirty-nine feet—the report on this subject will be found in Appendix H, page 858. This report is offered as information. The Committee does not consider the time opportune to increase the length of rail, so we make no recommendations.

Subject (8), redesign rail sections heavier than 100-lb. At the last convention the Committee offered, and the Association adopted, the 131-lb. rail section. Immediately after the convention, work was started on a rail section to take the place of the 110-lb. A section was finally submitted to the Association by a letter-ballot and was adopted by a very large majority.

In connection with the adoption of these two new sections, the 110, 120, 130, 140 and 150-lb. sections that were in the Manual were withdrawn, so that the standard rail sections are now the 90-lb. RA-A, the 100-lb. RE, the 112-lb. RE and the 131-lb. RE.

The next assignment of the Rail Committee is that of designing joint bars to go with the new sections of rail. This is quite a live subject; in fact, it is hotly alive. The

Committee went right to work on it. As a result there was presented for letter-ballot in January the joint bar and assembly for the 112-lb. RE rail. This is given in Appendix K. This joint bar and assembly was adopted by the Association by a vote of about three to one.

The Committee made the 131-lb. joint bar and assembly the subject of a supplemental report which was issued on March 5, in which the adoption of the joint bar section and assembly as standard is recommended. Within the past two days a question has been raised, the settlement of which is desirable before action on the adoption of the 131-lb. joint bar section is taken by the Association.

While the Committee feels confident that the outcome of the matter will be satisfactory, we consider the proper course to take is to withdraw, for the time being, the recommendation to adopt the joint bar section.

The other recommendations connected with the joint bar and assembly, such as the punching of the bars, the drilling of the rail, the lengths of the bars, the details of the bolt, should be acted upon at this time.

Referring to the supplement to the Rail Committee report offering the 131-lb. joint bar, the first recommendation shown on the second page, the adoption of the 131-lb. RE joint bar section is withdrawn. We will present it at some later time.

The second recommendation, "Change height of bolt hole above base of rail for the 131-lb. RE rail section adopted by the Association in 1933 from 3-1/4 in. to 3-3/32 in." is recommended, and I move that it be adopted.

I might say that these changes are in line with the recommendations for rail drilling and joint bar punching made by the Coordinator of Transportation last fall to be used with the 112-lb. and 131-lb. rail sections, so they are practically established now, but have never been acted upon by the Association for the 131-lb. rail. This spacing has been adopted for the 112-lb. rail by the letter-ballot on the 112-lb. joint bar.

The President:—The motion before the convention is Recommendation No. 2, to change the height of the bolt hole above the base of the rail. Is there any discussion? Are you ready for the question? All those in favor will signify by saying "aye"; contrary-minded. It is carried.

Chairman Earl Stimson:—The third recommendation: "Adopt the 24 in. and 36 in. joint bar bolt hole spacing shown on the print of the 131-lb. RE rail joint and assembly, dated February 19, 1934, which accompanies the report." I move its adoption.

The President:—It has been moved and seconded to adopt the 24 in. and 36 in. joint bar hole punching. Is there any discussion? All those in favor will vote "aye"; contrary-minded. It is carried.

Chairman Earl Stimson:—Recommendation No. 4: "Adopt the rail drilling for the 131-lb. RE rail section shown on this print"

I move its adoption.

The President:—It has been moved and seconded that we adopt the rail drilling for the 131-lb. rail. Is there any discussion on this question? All those in favor will signify by saying "aye"; contrary. It is carried and so ordered.

Chairman Earl Stimson:—The fifth recommendation: "Adopt as a whole the plan for assembly for the 131-lb. RE rail." This omits the rail joint section but covers all the rest of the details—the bolt hole spacing, the drilling of the rail, the punching in the bar, and the bolt and nut. I move the adoption of this recommendation.

The President:—It has been moved and seconded that we adopt the assembly for the 131-lb. RE rail. That is Recommendation No. 5, with the words "joint bar and" omitted. Is there any discussion on this motion? All those in favor will vote "aye"; contrary. It is carried and so ordered.

Chairman Earl Stimson:—We now come to the Revision of Manual, Appendix A, which will be presented by Mr. Blaess.

Mr. A. F. Blaess (Illinois Central):—Revision of Manual will be found on pages 830 and 831 of Bulletin 363.

"The following changes and additions of Definitions beginning at page 135 of the Manual, are recommended:

"Add note after definition for Alloy Steel:

" 'The above definitions for iron and steel apply to joint bars, bolts and spring washers as well as rail'

"Insert in alphabetical order under heading Manufacture, the following additional definition:

" 'Cobble.—In a rolling mill, any steel which has become bent or twisted so that it cannot be finished by rolling is termed a 'Cobble'.

" 'Hotbed.—A series of skids on which rails are placed for cooling after rolling, cambering and sawing.' "

Substitute for the present definition of Crop End, the following:

"Crop End.—A piece cut from the end of a bloom or rail during manufacture."

The next is merely a correction. "Remove the word 'with' in definition of Compound Fissure, line 2, page 16 of 1932 Supplement to Manual, Bulletin 347."

I move the adoption of the change and the addition to the definitions just read under the heading of "Definitions" for publication in the Manual.

The President:—The adoption of the definitions has been moved and seconded. Is there any discussion on this subject? All those in favor say "aye"; contrary. It is carried.

Mr. A. F. Blaess:—Under the heading of Rail Specifications the following corrections or changes are recommended:

"Section 6, page 149: A request having been received for height of drop to be used in applying drop test to 70-80-lb. rail, the following addition is recommended:

" 'For 70-80-lb. rail inclusive.....17 ft.' "

I might add that this is in accordance with A.S.T.M. standards.

"Section 12, page 150: Add 'or drawings' after word 'templets' in line 2.

"Substitute: 'width' for word 'length', line 4.

"Section 20 C, page 152: In order to avoid payment for weight in excess of the one-half of one per cent overrun allowed in Section 13, it is recommended that the words 'subject to limitation of Section 13' be added making this subsection read—

" 'Rail accepted will be paid for according to actual weight subject to the limitations of Section 13.' "

I move the adoption of these changes and additions for publication in the Manual.

The President:—You have heard the motion. Are there any recommended changes on the rail specifications? All in favor vote "aye"; contrary "no." It is carried.

Mr. A. F. Blaess:—Under the heading "Drilling of Rails" the following corrections or changes are recommended:

"(1) Paragraph 1, page 162: Elimination of this general recommendation as unnecessary and inadvisable, as specific directions for drilling are elsewhere given. This includes the necessary renumbering of the succeeding paragraphs.

"(2) Page 162: Revise data under heading 'Application of Recommended Rail Drilling to Standard Rail Sections,' to include only the present standard sections, as follows:

Weight of Rail, Lb.	Type of Rail	Height of Bolt Hole Above Base of Rail, Inches
90	RA-A	2-37/64
100	RE	2-45/64
112	RE	2-7/8
131	RE	3-3/32

"This eliminates sections which are no longer standard and adds data for the 112-lb. and 131-lb. RE sections.

"(3) Page 162: Revise the sentence, 'The standard drilling for rails should be as shown in the following diagrams' to read, 'The standard drilling for standard rails up to and including 100 lb. per yard should be as shown in the following diagrams.'"

I move the adoption of these changes and additions as shown under the heading "Drilling of Rails" for publication in the Manual.

The President:—It has been moved and seconded that we adopt for publication in the Manual this drilling of rails. Is there any discussion on this subject? All those in favor will signify by saying "aye"; contrary. It is carried.

Mr. A. F. Blaess:—Under "Specifications for High Carbon Steel and for Quenched Carbon Steel Joint Bars" (1929 Manual, pages 166-169):

"In order to keep the same terms in all Rail Committee specifications, substitution of the word 'heat' for 'melt' wherever the latter is used is recommended.

"While title of these specifications refers to joint bars, there are a number of references to splice bars on page 169. Recommend uniform use of the term 'joint bars.'

"Paragraph 13, page 169, last line: Recommend quenching temperature be shown in degrees Fahr. and degrees Centigrade enclosed in parentheses."

I move the adoption of those changes for publication in the Manual.

The President:—There has been moved and seconded the adoption in the change of Specifications for High Carbon Steel and for Quenched Carbon Steel Joint Bars. Is there any discussion on this subject? All those in favor will vote "aye"; contrary. It is carried and so ordered.

Mr. A. F. Blaess:—Under the heading "Revision of Form 402 A":

"Following changes are recommended, pages 180-181 of Manual: Face of form, item 38—Change 'Horizontal Fissure' to 'Horizontal Split Head.'

"Back of form—Under 'Description of Rail Failures', add new definition 1 B as given on page 16, Bulletin 347: (B) 'Compound Fissure—A horizontal split head which in developing extends into a plane other than horizontal'.

"Designate definition for 'Ordinary Break' by (C) instead of (B) and in third line of same substitute word 'compound' for word 'horizontal'.

"4. 'Split Head'—Change title to 'Vertical Split Head'.

"Add a new definition 5 as given on page 16, Bulletin 347: 'Horizontal Split Head' —'A horizontal progressive fracture originating in the interior of the head of rail usually indicated on the side of head by longitudinal seam or crack and flow of metal.'

"Renumber definitions 5, 6 and 7 as 6, 7 and 8.

"Eliminate the word 'Internal' under the cut of 'Internal Transverse Fissure'."

I move the adoption of these changes in the Manual.

The President:—It has been moved and seconded that we adopt the changes recommended in the Revision of Form 402 A. Is there any discussion on this subject? All those in favor of this motion will vote "aye"; contrary. It is carried.

Chairman Earl Stimson:—The rail investigation to determine the causes of transverse fissures and their remedy, that is being carried on at the University of Illinois, has progressed as per schedule. I know you are all very anxious to learn what has been done. Prof. H. F. Moore, who has charge of that work, has kindly consented to be with us this evening and tell us the story.

Prof. Moore, we will be glad to hear from you now.

(Prof. Moore described the experimental work carried on at the University of Illinois, and illustrated his remarks by lantern slides.)

The President:—That concludes the report of the Rail Committee. This Committee has had very important assignments. It keeps us posted on developments in the rail

problem. They have had a very difficult assignment this year, that of preparing plans for rail joints. We appreciate the work they have done, and now we will excuse them with the thanks of the Association for their good work (Applause).

Mr. E. E. R. Tratman, Civil Engineer—(by letter):—With reference to the proposed standard joint bars or splice bars and joint assembly for the new 112-lb. rail section, it is disappointing to find that the call for ballot votes gives no information on the basis of the design, either as to the form of cross-section of the bars or as to the bolt spacing of 5⅛-inch and 6½-inch, which differs from the uniform spacing of 5½-inch now recommended in the Manual. Thus there is nothing to guide or inform in the casting of the ballot. Apparently the section of the splice bars is such that the rail cannot be held down by spike heads on the joint ties, the spikes being reversed so that they only prevent lateral motion. It would seem somewhat undesirable to adopt a type of rail joint as the Association's standard without further knowledge of the basis of its design, or opportunity for adequate examination and discussion of the design.

DISCUSSION ON STRESSES IN RAILROAD TRACK

(For Report, see Bulletin 358)

Dr. A. N. Talbot (University of Illinois):—The Sixth Progress Report is printed in Bulletin 358. As it contains 240 pages and includes many tables and diagrams, I shall not attempt to read it or even to make a digest of it. Let me say concerning this report that time and thought were given to its writing to make it clear and explicit, without being too bulky. At best, it is not easy reading, not a primer, not a novel. It will require careful reading and some study. I hope it will repay study to those who are interested in the topics discussed.

The field taken up in this report is much the same as that of the Fifth Report—(1) the rail-joint, and (2) variability in the structure of the track and the need for greater uniformity. Last year and the year before I talked on some of the matters which have been included in the Sixth Report. It does not seem necessary now to go over the same ground.

I want, however, to state again some of the relations between the size of rail, the stiffness of the substructure (using the term "substructure" here to represent the ties, ballast and roadbed—in other words the rail support), the depression of the rail all along its length, and the distribution of tie pressure reactions, which may not generally be accepted or fully understood.

Relation of Tie Pressure to Size of Rail and Stiffness of Sub-Structure.—First, let me remind you that for track with small irregularities of play between rail and tie and tie and ballast bed, the loads or pressures on individual ties for a given track are proportional to the depression or lowering given to the rail by the wheel loads.

In the reports of the Committee, the term "modulus of elasticity of rail support u" has been used to express the relation between the magnitude of a load applied all along the rail and the magnitude of the resulting depression or vertical movement of the rail, it thus being a measure of the stiffness of the rail support or substructure below the rail.

The analysis of track as an elastic structure (checked by tests) shows that the rail depression for a group of closely spaced wheels varies only slightly with the size of the rail, whether 90 or 130-lb. per yd. Take the depression of the main driving wheel, it does not differ far from being inversely proportional to the modulus of elasticity of the rail support used, regardless of the weight of the rail. The values for the other drivers are similarly nearly inversely proportional to this modulus. The weight on the drivers is evidently supported by about the same length of track, and the average depression

of rail along this length of wheelbase does not vary greatly, regardless of rail stiffness, and this average depression is nearly inversely proportional to the modulus. Take, for example, a modulus of 1500 which is average track, and 3000 which is much stiffer track. The depression of the first track will be twice that of the second track, and the vertical movement of rail, tie and ballast is double. For the wheels of two trucks of two coupled cars, which is another condition involving high pressures, as well as high stresses, similar relations are found.

Since the intensity of rail pressure on a tie is proportional to the rail depression and to the modulus u, it follows that upward pressure against the rail at the main driver is nearly the same for any rail section and any rail-support stiffness. This, I think, has not usually been so accepted. For other driving wheels than the main driver, the relation existing between intensity of pressure and rail section and the modulus u does not vary greatly from uniformity. In other words, the pressure of rail on individual ties at or near the main driver (and to nearly the same extent at the other drivers) differs little for the several weights of rail and for the range of values of the modulus u. This fact may well be kept in mind in considering the loads coming on ties and ballast.

Verification of these statements may be seen by reference to Fig. 91 and 92 and the nearby text of the Sixth Report. Fig. 91 shows the vertical movement of the rail for a Mikado locomotive; these distances are proportional to the magnitude of the tie pressure for a given modulus u. Fig. 92 shows similar relations for the four wheels of two coupled cars on one rail. It will be found that the maximum tie pressure at a wheel of the two trucks of two coupled coal cars will not differ much for the different rails for different values of the modulus. For long trains of heavy cars the tie loads of these coupled trucks become an influential factor in producing deterioration of track surface. It may be expected, then, that the average tie pressure within a group of closely spaced wheels, whether for locomotive or coupled cars, will not differ greatly through the usual range of rail weights and rail-support stiffness.

Assuming, then, that the average tie pressure throughout the length of a given group of wheels due to given wheel loads is approximately independent of the rail section, and, likewise, independent of the stiffness of the rail support, attention may be directed to the vertical movement of the rail support when this group of wheels moves along the track.

Effect of Up-and-Down Movement.—The vertical movement of the rail (rail depression) at one of the four wheels of the trucks of two coupled cars, as the wheel loads are applied, for our comparison may be taken at about 0.25 in. for a modulus of 1500, and 0.10 in. for a modulus of 4,000. This means that the rail and the top of the tie will move downward, for the less stiff support, say, two and one-half times as far as they do for the stiffer support. The downward movement within the ballast under the tie will have a somewhat similar ratio of movements. All the movements are followed by a corresponding rise when the wheels have moved on.

This up-and-down motion under application and release of pressure to the tie every time a group of coupled trucks moves by (with approximately the same magnitude of tie pressure, whether the vertical movement be 0.25 in. or 0.10 in.) is a form of repetitive loading which, of course, has its effect on the stability of the structure and on the constancy and duration of good line and surface and on the ability of the ballast itself to continue to fully resist the load.

It is apparent that the effect of repetition will vary in some way with the magnitude of this vertical movement, and that the energy applied by a group of wheels will vary with the amount of the vertical movement. With 100 or 150 heavily loaded cars the

repetitive up-and-down movement of the ties and ballast at every group of car wheels puts a repetitive loading of high magnitude on the track substructure.

Value of Stiffness of Substructure.—All this has a bearing upon the value of increased stiffness in the tie and ballast substructure and upon the condition of the substructure. Although quantitative relations are not known, it is to be expected that the less stiff track (for example, that with a vertical movement of 0.25 in. as compared with 0.10 in.) will be put out of form with the passage of much less traffic, especially if the track is variable in condition from point to point and tie to tie. And of course the nature and depth of the ballast material and its consolidation and stiffness, as well as the quality of the tie structure, will largely determine the stiffness and depression of the substructure.

Such a finding is only a restatement of common knowledge, that a substantial substructure having deep, consolidated ballast on a solid roadbed will carry a much greater amount of traffic without maintenance work than will a less stiff substructure. It should be accepted that a stiff substructure has a real value in carrying heavy traffic. I do feel that the quality of substructure should not be overlooked when we are talking about weight of rail and other track matters.

Value of Uniformity of Track.—Last year I spoke of the ill effects of variability in track, variability from tie to tie and from point to point along the track. I want to ask again: Is not the search for methods and means of getting reasonable uniformity worth while?

Value of Heavier Rails.—The greater stiffness of the heavier rail sections has frequently been considered of value as carrying the load farther ahead or behind the wheel and of decreasing the load on individual ties. As has been seen from the relative rail depressions the greater stiffness of the heavier rail does not correspondingly affect the springiness or resilience of the track in taking sudden changes of load applied through defective rolling stock or by abnormal dynamic augment of an imperfect counterbalance. It is the stiffness of the substructure that mostly governs the springiness of track under a group of wheels, though the stiffness of the rail will take a local part in the spring, particularly when the increased load is on only one wheel as with the dynamic augment of the main driving wheel. However, other advantages which come with the added stiffness of rail give value to the heavier section.

Under the heading of stability of rail in the Sixth Report the following statement may be found: The greatest value of the heavier rail may be said to be the greater stability it gives to track. Stability implies the ability to maintain favorable conditions, to resist unusual or unexpected forces or loads, to overcome the variations. The greater stiffness of a heavier section aids in carrying loads over imperfectly tamped track and irregular supports; it resists lateral thrusts and lurches without undue distortion of alinement; it aids in maintaining proper surface. Even the added mass of the heavier rail gives an element of stability. The added stiffness should be considered a help in reducing the costs of maintenance.

It may be added that the value of the increased size of rail will depend upon many circumstances, among them amount and nature of traffic, nature of substructure, wheel loads and speeds, and any economies involved in the situation. It can hardly be expected, however, that this value may be expressed quantitatively in formulas and equations, but studies of accompanying conditions should be helpful in forming a judgment.

Lateral Strength and Stiffness of Joint Bars.—Questions have been asked in the Rail Committee about the lateral stiffness and strength of certain sections of joint bars. To what extent the bars and rail in any rail-joint act integrally in resisting lateral forces depends upon the fit between bar and rail and upon the bolt tension.

To the question raised concerning the comparative lateral strength of the angle bar joint used with the 127-lb. rail of the New York Central Railroad and a joint with study section G for 131-lb. rail described in the Sixth Report the answer was made that from the tests and analyses on rail-joints, assuming proper fit and bolts tight or moderately tight in both cases, the effective lateral strength of the joint having study section G bars would be more than 50 per cent greater than that of the New York Central angle bar joint. Possibly the advantage might be nearly double. Reference is here made to a lateral load within allowable bending and distortion in track—no attempt was made to find ultimate carrying load. With low bolt tension there would be much less difference, and neither would do well.

The foregoing applies to both tangent track and curves. On the sharper curves the greatly increased lateral forces may tax any form of rail-joint.

It should be said that the G section referred to is somewhat heavier and stronger than the section for 131-lb. rail reported by the Committee on Rail.

Tests and Inspection of Worn Joint Bars.—The staff has started laboratory work on worn joints to find the characteristics of their action under various conditions. Inspection tests have been started on track having built-up bars in the joints. This work will be continued.

Counterbalance Calculations.—Counterbalance of locomotive driving wheels continues to be of interest. That topic has been assigned by the Committee on Outline of Work and the American Railway Association. Cooperation with the Mechanical Division is planned. Little opportunity has been found beyond what was done several years ago. It seems well, however, to present some comparisons of counterbalancing for locomotives of the old Santa Fe type, with small driving wheels, diameter 63 in., rather difficult to counterbalance, as an example of what has been done by one railroad.

A locomotive similar in design to one used in tests we made on track more than fifteen years ago has recently been modified by equipping it with a new form of main driver, a double disc wheel, which permits the placing of a much heavier counterweight, 1,000-lb. A comparison will be made first of the calculated rail stresses for the old locomotive and the modified locomotive and second of the rail depressions of the two locomotives. In the calculations, following the practice of mechanical departments, for the purpose of a comparison a diameter speed has been used, 63 miles per hour, a speed higher than these locomotives should be run.

Fig. 1 gives the stress in rail at various places along the locomotive. The upper diagram shows by the vertical ordinates the calculated stresses in the rail at and between

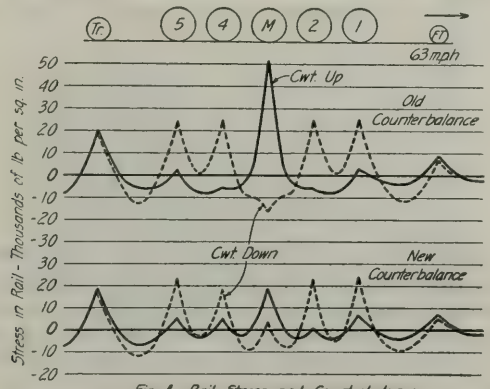

Fig. 1 Rail Stress and Counterbalance

wheels for the old counterbalance on the locomotive that was tested. The heavy line shows values with the counterweight up. The magnitude reaches 50,000-lb. per sq. in. at the peak for the main driver. The dotted line gives the stresses for counterweight down. The effect is seen to be different. The counterweight on the main driver was very much smaller than what it should be, though as large as there was room for. The locomotive was far from being balanced.

The lower diagram shows the stresses for a similar locomotive, not on the same railroad, on which has recently been installed a new form of main driving wheel that gives opportunity for providing an adequate counterweight. In some ways the two locomotives are not the same, but the comparison is a fair one.

The counterweight of 1000-lb. on the main driving wheel has reduced the maximum stress considerably, though it should be said that in the change the main drivers were cross-counterbalanced. However, attention is called to another difference—the upper locomotive had comparatively little counterbalance for the reciprocating parts, and the counterbalance of the lower locomotive follows the regulations of the Mechanical Division in taking one-half of the weight of the reciprocating parts and counterbalancing for this amount. This desired counterweight has been divided among the four drivers, other than the main driver. It is a pertinent question whether so large a proportion of the reciprocating parts is necessary in the counterbalancing.

Fig. 2 deals with rail depressions. Bear in mind that these rail depressions are proportional to the tie pressures, practically so. The line for static loading is shown. The heavy line represents the counterweight up. For the locomotive with the old counterbalance the depression under the main driver is 0.68 in.; under the end drivers the depression is only about 0.1 in. Correspondingly, the load on the ties under the main driving wheel would be more than six times as great as under the end drivers. For the counterweight down there is a somewhat similar form of curve, showing the great variation in tie pressures and in depression of the rail.

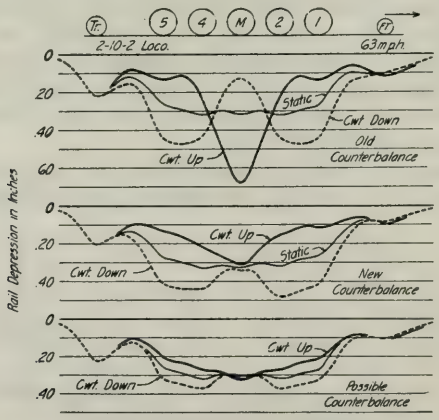

Fig. 2 Rail Depression and Counterbalance

The middle diagram shows the rail depressions for the locomotive with the new main wheel and new counterbalance. It will be seen that the depression under the main driver is about the same regardless of the position of the counterweight, and this condition exists with no extra counterweight applied to this wheel to balance any of the reciprocating parts. For this locomotive half of the weight of the reciprocating parts was counterbalanced by dividing it among the other four drivers. For these four drivers

there is a great difference between the depression for counterweight up and counterweight down.

The lower diagram shows what would have happened if the proportion of the reciprocating parts used in counterbalancing the old locomotive had been applied to the present locomotive. In this case the depressions and, therefore, the tie pressures will not vary very much as the train runs along the track, which, of course, is a much more favorable condition.

A somewhat similar comparison might be made on the effect of imperfect counterbalance on bridges. It may be said further, that in a variety of ways the design and condition of rolling stock affects the maintenance of the track, and, likewise, the design and the condition of the track affects the operation and maintenance of both locomotive and cars. This interrelation is worthy of a more extended study.

Pere Marquette Concrete Roadbed.—Last fall a brief test, lasting two weeks, on the stretch of track of the Pere Marquette Railroad having a concrete roadbed was conducted with a view of learning something of the action of this type of roadbed. Although the data have not been finally worked up, it may be of interest to report some of the results. Tests were made on the two forms of construction. In the older one built several years ago, the rather thick rectangular slab rises to the level of the rail. The newer one has a lighter base slab and two longitudinal supporting members continuous with the base, one under each rail, and having cross braces between these members. I will not describe the form of the roadbed nor the method of fastening the rail to the slab. Many of you are familiar with the construction.

What will be of interest is the magnitude of the stresses in rail and their approach to uniformity, and also the amount of the rail depression and the distribution of the reaction pressures on the rail. The older stretch of track has the rail laid on a thin strip of composition material, insulating fiber, which rests directly on the concrete. This strip is about ⅛-inch thick, the width of the rail base, and rather hard. For the newer form the rail base rests on a ⅞-inch creosoted pine board, a little narrower than the rail base, and this rests in a shallow groove in the concrete. The general appearance is shown in Fig. 3. The space between the longitudinal members, a few inches deep, is filled with ballast.

Fig. 3 Pere Marquette Concrete Roadbed

In the test a static load was used, a 30,000-lb. wheel load on each of the four wheels of one truck of a coal car—a very heavy load of course. Calculations for the conditions of the good second tie-and-ballast track alongside the concrete roadway indicated a mean stress in base of rail of 15,000-lb. per sq. in. with the given test load. In the newer stretch, the one in the picture, the average of the stresses in base of rail found at 78 spots was 6,800-lb. per sq. in., a little under half of that calculated for the tie-and-ballast track. On the older stretch, at 33 spots, the average stress in base of rail was 3,800-lb. per sq. in., about one-quarter of that calculated value for the tie-and-ballast track. The difference in the value of the stresses in the two stretches of concrete roadway is due principally to the greater compressibility of the wooden strip used as a rail support in the new stretch over that of the thinner and harder strip in the older stretch.

Let me say that less variation in stress from point to point was found as compared with tie-and-ballast track. The board is a better support than the thin, hard insulating fiber. It takes up the variations and has some elastic action. As is to be expected, the slabs gave a good account of themselves. The depression of the slabs under the load averaged .06-inch for the newer slab and .04-inch for the older slab. In addition to the depression of the slab, the rail has a further depression which averaged .09-inch on the newer slab and .05-inch on the older slab, making .15-inch and .09-inch in all. This additional depression is made up of the compression of the wood and the play. Variations in play found between rail and supporting strip and concrete contributed to the variations in depression and stress found in the tests.

It may be remarked that the way of supporting the rail on the slab is of importance and to some extent is experimental. In these tests the results showed very fair uniformity of stress and depression and a much stiffer roadbed than the usual type of construction.

Bearing Between Rail and Tie-Plate under Load.—This afternoon in the discussion of the report of the Committee on Track I referred to calculations to show the position of the bearing between the rail base and the tie-plate under load.

Analyses were made on several assumptions of the position and manner of the bearing between rail base and tie-plate. Calculations were made of the curves of flexure of both rail base and tie-plate when supported by the compressible wood of the tie. The consistency or inconsistency of the deflections of rail base and tie-plate under load were studied. In Fig. 4 are given flexural curves for rail base and tie-plate for a central load on the rail with an assumed distribution of the tie reactions shown at *A*. Several plausible assumptions for the position of the bearings between rail base and tie-plate were dismissed as impossible after comparison of the curves of flexure found. Then the assumption was tried that one of the resultants of the reactions between rail base and plate is located ¼-inch within one edge of the base and the other at ¼-inch within the other edge. The curves of flexure at *C* in the figure show that this assumption gives contact between rail and plate only at the middle of the width (the rail flanges curling up from the plate), a result wholly inconsistent with the assumption. Assuming that the resultants of the reactions between base and plate are located at ¾-inch from edge of base, the curves of flexure

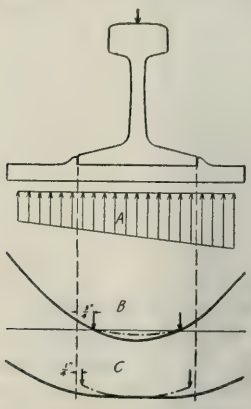

Fig. 4 Flexure of Rail Flange and Tie-Plate

were found to be as shown at *B*. These curves show no contact between base and plate through the middle portion and indicate that the reaction resultants are somewhat outside of the ¾-inch point. Further computation for resultants at ½-inch inside the edges of base gave curves of flexure that are consistent with the assumption used.

Other calculations were made for loads applied away from the middle of the head, and varying farther from the vertical direction, and with other dimensions of the tie-plate. It was concluded that a point ½-inch inside the rail edge would be a suitable position to consider as the position of the reaction resultant in calculations for the stresses developed in rail flanges and tie-plates. It is true of course for wheel loads applied in a way that gives a very large lateral thrust, or for tie bearings that produce similar large lateral forces, that the resultant may be so inclined as to act through one edge of the rail base (and only one) and thus that a much higher flange stress will be developed.

The deflections of the curves of flexure found are very small, but they fix the bearing contacts when the rail base and the tie-plate have plane surfaces that are in contact in an unloaded condition. If the surfaces are convex to each other when unloaded, the rail will rock under an applied load. If the surfaces are concave to each other the bearings under load will be nearer the edge of the rail base than was reported above. If the surfaces are irregular a position nearer the edge should be assumed. In general a position of the reaction resultant a half-inch or less from the rail edge may properly be made the basis of strength calculations.

Long Length of Continuous Rail.—In conclusion I want to refer to a piece of track, not tested by us, where an interesting experiment is in progress on a long length of continuous rail. Reports from Germany on long stretches welded into continuous rail have been of interest. The practicability of long lengths of rail is, of course, largely a matter of time tests. Although the Committee has had no part in planning this, it seems well to call attention to one of the longest stretches of rail in this country.

Last August the Delaware and Hudson Company at Albany, New York, laid 130-lb. rail and welded it in continuous stretches of 2,800 ft., 2,300 ft. and 500 ft., partly on curves. The track is a very substantial structure in every way. Mr. Clarke, the Engineer of Maintenance of Way, says that inspection and measurements will be made on this track to learn its behavior.

Here is one opportunity to get information on whether, in our northern climate, the matter of changes of temperature and other influences, together with need for maintaining and repairing track during hot weather, will interfere with the satisfactory use of such long rails. The results should be of interest and value. Mr. Clarke has extended an invitation to the Committee to make such inspection and test as may be desired.

I understand that other railroads have made similar installations.

The President:—I am sure we all realize the importance of this very difficult research work that is being carried on by Dr. Talbot and his Committee. I wish, however, to mention to the various Committees the importance of their application of the knowledge obtained from this research work in the study of their particular problems. It is of inestimable value to many of our Committees, such as Ballast, Ties, Track, and others, and they will do well to study Dr. Talbot's reports. They will find information that will help them very much.

Dr. Talbot, on behalf of the Association the Chair desires to express appreciation to you and your Committee for your very excellent work (Applause).

DISCUSSION ON TIES

(For Report, see pp. 779–828)

Mr. W. J. Burton (Missouri Pacific):—The report is contained in Bulletin 363. We will start with Appendix B on page 782. This subject is one which the Committee has had for a number of years. I will ask Mr. Foley, Chairman of the Sub-Committee, to make the presentation.

Mr. John Foley (Pennsylvania):—Appendix B is on page 782. The adherence to specifications for ties by railroads in general and the increased belief in standards for ties by the manufacturers of them is exceedingly gratifying to those of us who take a special interest in that phase of railroad maintenance.

The Committee each year becomes more and more convinced that wherever substandard ties are produced in any quantity, the reason lies in laxity of inspection by railroads. The only possible excuse there is for accepting substandard ties lies in an attempt to cover up a substandard price.

Should code prices go into effect, there would be no excuse for any railroad to accept substandard ties. Consequently, this report is submitted as an admonition as well as information.

The President:—This report will be received as information. If there is anyone who would like to ask Mr. Foley any questions, we will be glad to have him do so.

Chairman W. J. Burton:—The next subject is also one which the Committee has had for a great many years. In fact, the subject of substitute ties was one of the very first to be assigned when the Association was first organized. The Chairman of this Sub-Committee is not here today. However, there is nothing of any particular novelty. The report merely contains the record for the year, in the same form as used previously.

The next subject is reported briefly on page 787, Tie Renewals Averages per Mile Maintained. This report is a compilation of tie renewal statistics obtained from reports made to the Interstate Commerce Commission by the different railroads. Previous to this year the report has not been available until the publication of the Bulletin containing the full Tie Committee report late in the year. Last year there was considerable demand for these statistics earlier, and it was therefore arranged to publish them in the June Bulletin. The demand for these statistics seems to be so great that they ought to be published as early as possible, and the Committee will therefore continue to publish them as soon as they are made available.

Last year, at the time the United States statistics were published, the data from the Canadian railroads had not been received. We are hoping to have the Canadian data on hand this year so that it can be published at the same time as the United States data. The figures in Bulletin 363, beginning on page 788, are for the three principal Canadian railroads and in the same form as the report for the United States railroads, published in Bulletin 356.

The next subject, Recommend Standard Spacing of Spike Holes for Ties Pre-adzed and Bored for Standard Rail Sections 90-lb. to 131-lb., inclusive, will be reported by the Chairman of the Sub-Committee, Mr. Chapman.

Mr. E. E. Chapman (Santa Fe):—In 1933 the Railway Tie Association presented a request to the American Railway Engineering Association that consideration be given to the standardizing of track and its parts for the more important rail sections as to

result in standardized adzing and boring of ties. In this they presented the advantages to the tie producer and to the railroad. Those of the tie producer were:

The regular and fairly uniform production of cross-ties; the standardization of ties in their treatment, which enables the manufacturer to be reasonably sure of the sale if his ties meet specifications; the growing practice of pre-adzing and pre-boring of ties which has taken away a part of the benefit of the present standard specification of ties because of the great variation in arrangement and spacing of spike holes.

The wood preserving plants are also greatly benefited by having uniform production; the reduction in templets, knives and bits, and patterns necessary to carry through standardization reduces their cost and makes the sale of the product more sure.

They also presented the advantages to the railroad, which, on final analysis, could be obtained more in the sections which are at present being designed for rails and their fasteners.

They also presented the questionnaire which they had sent out to the various railroads and the answers. These were analyzed, and the results show a lack of agreement, and in Exhibit B for 110 and 130-lb. rails on page 797 this is brought out clearly.

There are only about ten railroads in the United States which own their own creosoting plants. Therefore, the standardization of boring and adzing of ties is important to most railroads and to a large part of tie treating industry.

A table has been prepared showing what may possibly be accomplished if the recommended standards of the Manual are followed. If the standards were adhered to it would be possible to adze all ties with a 12½-inch adzing length, and this would take care of all the present A.R.E.A. standards as to length of tie plates.

The recommendation of the Special Committee on Stresses in Track was that the eccentricity of tie plates should not be over ⅜ in. There is considerable variation in the arrangement and spacing of the spike holes. Where four spikes are used per tie plate, the variations in spacing are from 1½ to 4½ in. A good spacing from the standpoint of the tie would be from 3 to 3½ in. between spike holes.

The following recommendations are made:

"1. In view of the interdependence between rail joint and tie plate design and the fact that as far as the tie is concerned, the standard for pre-boring and adzing can be made to conform to the design requirements for joints and tie plates, your Committee respectfully suggests that this subject be reassigned to the proper committee, with instructions to consider the following suggestions in preparing a standard or standards of tie plates which will result in standardized adzing and boring:

"1. A single standard of cant.

"2. A standard distance between centers of spike holes in all tie plates at the edges of the rail base.

"3. The lengths and eccentricity of tie plates to be standardized.

"4. A standardized location for the grooves cut in the cross-ties, both as to distance between the two grooves under each rail and the distance (gage) between the grooves under one rail and those under the other rail so that all cross-ties may be pre-grooved to a single standard regardless of the rail section to be used, making the necessary accommodations for different rail sections in the designs of the tie plates for different rail sections.

"5. To particularly expedite standards for plates and boring for the new 112-lb. and 131-lb. rail sections."

The President:—The recommendations of this Sub-Committee will be given consideration by the proper committee. The report will be filed as information. Are there any questions you would like to ask the Committee on this subject?

Chairman W. J. Burton:—The next subject, A Method of Predicting Tie Renewals, including a Period of Change from Untreated to Treated Ties. This subject may, on

first reading, appear rather innocent, but I want to assure you that it is something on which we have done a great amount of work. It points out new ideas which I am sure will be new to a great many maintenance men, and points a way to the supervision of tie renewals and related matters, which will be most helpful in promoting ultimate economy. This report has been prepared by Mr. Crugar, who will present it.

Mr. E. L. Crugar (Wabash):—The report of the Sub-Committee will be found beginning on page 798 of Bulletin 363. Your attention is called to a typographical error in the fourth line of the second paragraph on page 799. This refers to Fig. 5 instead of Fig. 6.

The report as it is here presented is the result of tabulations and charts in such volume as to make it impossible to present all of the details. We have endeavored to present the suggested procedure to be followed in the working out of your own problem of predicting tie renewals on whatever average life you may be obtaining from the grades and quality of ties you are using. The so-called 8, 10, 20 or 25-year ties on one road may be something else on another road. In this connection your attention is called to the last paragraph on page 799, Comparisons of Ties Renewed per Mile. When all is said and done, your own tie requirements per mile, or on any other unit that may be designated, is measured by what you are getting from the tie used. Comparisons are very valuable but to be of value they must be reduced to a comparable basis. The report is submitted to you as information. Whether it is of value is left for your determination. We believe the assignment has been completed, but, nevertheless, we will gladly answer any inquiries that members may write us in regard to the subject, and if reason is shown for revision, the subject can be reopened for that purpose.

The President:—The report will be received as information, but I am sure the Committee would like to have some discussion on this very interesting subject.

Chairman W. J. Burton:—I should like to start a little discussion by pointing out some of the high spots in this report. In the first place, I want to urge every maintenance man who has to do with tie programs to go into it far enough to get the idea. It is very difficult to get it unless you actually go through the motions of making these estimates.

One of the important points is that there are practically no roads, I think I could say there are no roads, using creosoted ties who have used them long enough for constant normal renewals, or for what the Committee calls the "normal annual renewals", to have become constant. In other words, the effect of changing from untreated to treated ties creates certain disturbances in the number of ties required this year as compared to last year, or next year as compared to this year, in such a way that that requirement of ties to merely maintain, not to improve nor to drop back, varies each year and varies very considerably.

It is commonly thought that when a road adopts high-class creosoted ties in place of untreated ties, it must wait for a very long period of years before it receives any substantial benefit. Some have thought that it must wait until practically all of the old ties are out of the track before any benefit is received. This report should convince anyone that that idea is very erroneous, and that the benefit begins to be felt after the second, third or fourth year, and that in a very short time renewals drop to even below the level corresponding with the average life of the creosoted ties. For example, if the creosoted ties have an average life of twenty years, corresponding with a 5 per cent renewal, the renewals in a few years not only will drop below 5 per cent but may even drop to zero. This is hard to believe, but it is exactly the way it works out.

Another important point which this report clears up concerns estimates of deferred maintenance. One easy method, and one which has frequently been followed in such estimates, is to obtain a normal renewal by a process of averaging renewals for three or four of what are considered normal years. For instance, we might average the renewals for the years '28, '29 and '30 and call that average our normal, and then perhaps make some adjustment for decrease in traffic, and then say that the difference between what we did renew and this normal represents deferred maintenance. But this method would produce a wholly erroneous result, a much greater figure than the true figure.

I want to call attention to the diagrams on page 800 and also the diagram on the opposite page. There is no theory connected with this compilation that is at all out of harmony with actual fact. If, for instance, we were to build a new railroad out of untreated ties which had a relatively short average life, the number of ties required each year for merely maintaining the track, not improving it or changing it, is represented by the upper curve.

You will notice that when the road is new, there is a considerable fluctuation extending over a period up to about 30 years. Beyond then the curve becomes almost a straight line. Where ties are longer lived, as shown by the lower curves, there is a similar vibration or variation in normal requirements. To be particularly noted are the great magnitude of these vibrations, that is the great variation from one peak to the next hollow, and that in the case of the long-lived ties, the period of years required before the renewals settle down to a constant normal is very great.

The change from the use of short-lived untreated ties to long-lived treated ties is indicated in the diagram on page 801. In this case it will be noted that the normal requirement actually touches the zero line in about twelve or thirteen years. There is nothing about that result which is not absolutely correct, as far as we can determine. Of course disturbances due to financial conditions, variations in traffic, and so on, will create minor irregularities in these curves, but if we stick to the definition that we are merely maintaining, and that we do not improve or do not lessen the degree of maintenance, these results are absolutely correct. I am sure it is a new thought to many that the tie renewal just sufficient to maintain is not constant year by year.

The next subject is reported on page 809, Type of Tie Plate Best Adapted for Use with Pre-adzed Ties. The Chairman of this Sub-Committee is absent and I will read the report as it is not long.

(Chairman Burton read the matter appearing on page 809.)

The President:—This report will be received as information. Is there any discussion? Are there any questions you would like to ask?

Chairman W. J. Burton:—The next subject is found on page 810, "Economy of Use of Tie Plates which are Secured to the Tie Independently of the Rail Fastenings, with Particular Reference to the Effect on Tie Life." This report will be presented by Mr. Bolin, Chairman of the Sub-Committee.

Mr. W. C. Bolin (Baltimore and Ohio Chicago Terminal):—The report of Sub-Committee (10) is to be found in Appendix H, Bulletin 363 on page 810.

There is an error in the twelfth line of the report. The sentence reading, "Spikes used with class (a) are usually cut spikes or lag screws," and so forth, should have the first word changed from "spikes" to "independent fastenings," so that it will read, "Independent fastenings used with class (a) are usually cut spikes or lag screws," and so forth.

On heavy duty track, rail is renewed several times during the life of a treated tie, with resulting abuse to the tie from adzing and spiking. Frequent re-adzing and re-spiking of the tie damages the tie fibers and permits easier introduction of moisture beyond the treated depth, with resulting decay and loss of holding power of the spike.

Some types of rail fastening used with independently fastened tie plates would appear to minimize this abuse.

Failure of the tie at the rail seat results from the mechanical wear and shattering, as well as from the decay and loss of holding power of the spike. Larger and heavier tie plates distribute the traffic load over a greater tie area. Independent fastening of tie plate reduces the amount of motion and friction between the steel plate and the wood tie. These have materially reduced the mechanical wear and shattering of the tie.

To the extent that the larger tie plates spread the mechanical wear over a greater tie area, even though accompanied by the use of more spikes, and to the extent that independent fastenings may make unnecessary re-spiking of the ties on account of rail renewal, widening gage or loosening of the spikes, the *abuse* of the tie is reduced and the *use* of the tie is increased—improved tie life may be expected.

The Committee makes no finding as to the economy that may be secured. The report is submitted as information.

The President:—The report will be so received. Is there any discussion on this subject?

Chairman W. J. Burton:—The next subject is Methods of Inspection for Renewal of Ties, Checking Thereof and Adherence Thereto. This, of course, refers to the inspection of the ties in track, not of the material. Mr. Belcher, Chairman of the Sub-Committee, will present the report.

Mr. R. S. Belcher (Santa Fe):—This report is on pages 811 to 828. The report this year is a digest of sixty-one replies to a questionnaire which appears on page 351 of Vol. 34 of the Proceedings. Your Committee has endeavored to consolidate the information contained in the replies to the questionnaire into a story of the methods used for the determination of annual tie renewals, including expressions of opinion relative to the use of these methods and possible improvement in them.

Your Committee takes this opportunity to express its appreciation of the hearty response of the Engineers who answered our questionnaire and the complete yet concise manner in which each phase of the subject was covered.

On these sixty-one railroads located in all parts of the country, it is to be expected that the wide range of conditions will call for a considerable variation in the methods used for the determination of annual tie requirements. Possibly no one method suitable for use under all conditions can be established. However, your Committee is of the opinion that the general conclusions given on pages 827 and 828 may be applied under most conditions. This report is offered as information.

The President:—It will be so received. Are there any questions you would like to ask Mr. Belcher?

Chairman W. J. Burton:—This completes the report excepting for the revision of the Manual. The suggested revisions are found on page 780 and the recommendations will be made by Mr. John Foley.

Mr. John Foley (Pennsylvania):—The Committee has been reluctant to make changes in the standard until they seemed almost necessary and highly desirable. The reasons for the proposed changes are enumerated in the report in connection with each recommendation.

Section 16 refers to the split in the tie. The changes simply are that instead of 10 in. being acceptable, the split is reduced to 5 in. and instead of the statement which implied that a single anti-splitting iron would be satisfactory, it is now made clear that effective protection from splitting may require more than one iron.

It is moved that the present form be changed to the proposed form and read:

"16. Split. One which is not more than 5 inches long will be allowed, provided sufficient satisfactory anti-splitting devices have been properly applied."

The President:—While it is not the custom of the convention to discuss definitions on the floor, a brief reference to the definitions or objections to them in their form will be received. However, if there is any particular change in the wording, that may be in the nature of editing, will you please take it up with the Secretary? You have heard the motion. Is there any discussion? All in favor say "aye"; contrary. It is carried.

Mr. John Foley:—The specification under which we have operated for the past dozen years has, under Dimensions, tolerances which seemed necessary at the time it was adopted. As the manufacture of ties has improved in character, those tolerances seem no longer necessary. Therefore paragraph 20 on Dimensions has been reduced to what becomes a very simple rule. Ties may not be any smaller than the standard dimensions called for, but they may in all cases, length, thickness and width, be 1 inch larger. The revised paragraph thus becomes:

"20. Dimensions. The lengths, thicknesses and widths specified are minima for the standard sizes. Ties over 1 inch longer, thicker or wider than the standard sizes ordered will be rejected."

The adoption of that change in the Specification for Cross-Ties is moved.

The President:—It has been moved and seconded that the change in Specification of Cross-Ties under the heading of Dimensions be adopted. Is there any discussion on this? All those in favor will vote "aye"; contrary. It is carried.

Mr. John Foley:—For the same reason a similar change is recommended in the Specification for Switch-Ties, and it is moved that paragraph 20 be changed as follows:

"20. Dimensions. The lengths, thicknesses and widths specified are minima for the standard sizes. Ties over 1 inch longer, thicker or wider than the standard size ordered will be rejected."

The President:—There has been moved and seconded the adoption of this change in Specification for Switch-Ties under Dimensions. Is there any discussion?

Mr. J. C. Irwin (Boston & Albany):—I just want to ask Mr. Foley if any study has been made as to the probable effect on the price of ties. Do you think there would be any effect?

Mr. John Foley:—No effect.

Mr. J. C. Irwin:—Have you satisfied the manufacturers that that will be the case?

Mr. John Foley:—Yes.

The President:—Is there any further discussion? Are you ready for the question? All those in favor will say "aye"; contrary. It is carried and so ordered.

Mr. John Foley:—In the Manual on page 121 there is an illustration of cross-sections of ties which are in harmony with the standard specifications. The changes which you have just adopted require correction of that diagram. At the foot of page 781 you will find what they are. In line 4, column 5, the thickness becomes 8 in. instead of 8 to 9 in., and the bottom width should be 9 to 12 in. instead of 9 to 15 in. In column 6 the thickness should be 8 in. instead of 9 in. In line 5, column 6, the width becomes 10 instead of 12 in. These necessary changes in that diagram are due to the action you have already taken in amending the specifications.

Their adoption is moved.

The President:—Is there any discussion on this? All those in favor will say "aye"; contrary. It is carried.

Chairman W. J. Burton:—That completes the report.

The President:—This Committee has for many years made contributions of great value to the information on cross-ties. Their report this year contains information that will be of advantage to the Track Committee in their design of tie plates. They will now be excused with the thanks of the Association (Applause).

DISCUSSION ON WOOD PRESERVATION

(For Report, see pp. 713–777)

Mr. F. C. Shepherd (Boston & Maine):—The report of Committee XVII—Wood Preservation, is found on page 713 of Bulletin 363.

The first report, Revision of Manual, is shown under Appendix A on page 714. This report will be rendered by Mr. Steinmayer, Chairman of the Sub-Committee.

Mr. O. C. Steinmayer (Canada Creosoting Company):—With a view to harmonizing the specifications of the various associations relating to the same product, the Committee has been collaborating with representatives of the American Wood Preservers' Association and the American Society for Testing Materials on creosote and creosote-coal tar solutions.

Pursuant to this, your Committee recommends the revision of present standards involving more particularly the withdrawal of clause 5 relating to the specific gravity of fractions and the addition of some footnotes which will aid in arriving at the authenticity of the product.

The character of tar has changed because of the increased proportion originating from coke ovens of modern design and method of operation, with the result that creosote distilled therefrom very often has gravities of the fraction 235 to 315, also the fraction 315 to 355, lower than those now embodied in clause 5. A lowering of the gravity requirements for these two fractions to the limit as embodied in the footnote therefore seems most advisable.

In these footnotes attention also is called to the presence of solids in the fraction between 210 and 235 deg. C. when cooled to 25 deg.; also the increase in quantity of insoluble matter in benzol, in creosote, due to changes in its characteristics after repeated use in treatment. Mention is made of the presence of tar acids in varying amounts in all fractions up to 315 deg. C. This reference to tar acids makes it necessary to adopt a standard method for their determination in creosote. All these remarks apply equally to creosote-coal tar solution as well as to creosote itself.

Grades 2 and 3 creosote under present conditions of the tar distilling industry are items of special manufacture. There appears to be no good reason why specifications for non-existing grades should be continued.

Your Committee therefore recommends a revision of the specification for creosote, grade 1, also a revision of the specifications for creosote-coal tar solution now appearing in the Manual, and the withdrawal of specifications for creosote, grade 2 and creosote, grade 3.

I move the revision of the present specifications for creosote, grade 1, to conform to the recommendation as shown at the bottom of page 715 and page 716 for publication in the Manual.

The President:—You have heard the motion, gentlemen, on the adoption of the revision of specification for creosote, grade 1. Is there any discussion on this subject? All those in favor will say "aye"; contrary. It is carried.

Mr. O. C. Steinmayer:—I move the withdrawal of specification for creosote, grade 2, and creosote, grade 3, now appearing on page 1287 of the 1929 Manual.

The President:—You have heard the motion. Is there any discussion on the withdrawal of the specifications? Has anyone any objection to their withdrawal? If not, all those in favor say "aye"; contrary. It is carried.

Mr. O. C. Steinmayer:—I move the revision of present specifications for creosote-coal tar solution to conform to the recommendations as shown in the lower part of page 716 and 717 for publication in the Manual.

The President:—You have heard the motion. Is there any discussion on this specification? All those in favor will say "aye"; contrary. It is carried.

Mr. O. C. Steinmayer:—I move the adoption of Standard Methods for the Determination of Tar Acids in Creosote as shown at the bottom of page 717 and continued to page 719, for publication in the Manual.

The President:—Is there any discussion on these standard methods for the determination of tar acids in creosote? All those in favor will say "aye"; contrary. It is carried.

Chairman F. C. Shepherd:—The second report of this Committee, Service Test Records for Treated Ties, is shown under Appendix B on page 719. In this report the Sub-Committee shows its table on tie renewals per mile maintained on various railroads, up to and including 1932, and submits reports of special test tracks on some five different railroads. This report is offered as information.

The President:—It will be so received. Is there any question you would like to ask in connection with it?

Chairman F. C. Shepherd:—Subject (3) Piling Used for Marine Construction is shown on page 729 under Appendix C. This report will be described by Mr. Atwood, Chairman of the Sub-Committee.

Mr. Wm. G. Atwood (Consulting Engineer):—This report is really a research report carried on from the work of the National Research Council and amplified by work which we have been able to initiate in the ten years since that organization was disbanded. We have received a very high degree of cooperation from the various governmental agencies, the Chemical Warfare Service of the Army and the Bureau of Yards and Docks of the Navy. So far as caring for the test specimens and making reports on them, it has really been very surprising the accuracy and care with which this work has been done. Further, the Chemical Warfare Service have, until the recent reduction in expenditures, been able to carry on a considerable amount of original research, looking for more economical and more efficient preservatives. Like all research, the results are still in question, but it is an extremely valuable thing to have this work being done as it has been done by the government agencies. There is no particular point to which to call attention in the report, except perhaps the success of the tests of some tropical timbers of Panama. The Governor of the Canal Zone has consistently been very interested in this subject, regardless of whom he might be. They are developing some information, particularly along the East Coast, which may ultimately be of great value to those responsible for the maintenance of marine structures.

Outside of the report there is one caution that I should like to bring to the attention of maintenance officers, and that is the extreme variability in the attack of marine borers. They go in waves. Places where there has been freedom from an attack, or that has had a light attack may at any time have an intensified attack.

I was talking with a marine biologist who did a large part of our work on the National Research Council Committee, only a few days ago, and he called my attention to a very heavy increase in the last two years in the attack of borers along the New England Coast. There have been many points in Massachusetts Bay where there never have been any borers, Plymouth being one, and several structures in that vicinity have been destroyed within the last two or three years. He said it was also true that borers had been found in the inner harbor of Boston where they have never been known before, and the attack in Portland was heavier. Therefore, the maintenance officers on

marine structures should keep very close watch of their structures, even though they have had no previous history of attack. How far that goes in connection with New York Harbor is a question. Just before I left home I heard a rumor of a heavy borer attack pretty well up the Hudson. Whether that is true or not I was not able to find out before I left. The report is offered as information.

The President:—It will be so received. This is very valuable information. If there are any questions you would like to ask the Committee, please do so.

Chairman F. C. Shepherd:—Report (4), Specifications for Treatment of Air-Seasoned Douglas Fir, is found listed under Appendix D on page 750. This report will be rendered by Mr. Belcher, Chairman of the Sub-Committee.

Mr. R. S. Belcher (Santa Fe):—The work of your Committee on this subject which began in 1928 may be divided into three parts: First, a study of the treatment of Douglas fir piling timbers which have given long service, the methods which were used for the treatment of this fir, and the penetration of preservative accomplished by these treatments.

Second, a study of the practice of incising or perforating Douglas fir ties and timbers, the improvement in penetration and absorption of preservative obtained thereby, and the effect of incising upon the strength of the timber; third, a study of the effect on quality of treatment of the various manipulations of the treating cycle, using experimental equipment but along the general lines of the treating methods now in general use.

The report of the study of the Douglas fir piling and timbers which have given long service appears in Vol. 30 of the Proceedings. The report of the study of incising and treatment manipulations appears in Vol. 34 of the Proceedings. This report also included the proposed specifications which were presented last year as information, with the recommendation that they be referred to other interested committees for consideration and criticism. These committees have approved the specifications, and your Committee is now presenting the specifications for inclusion in the Manual.

I should like to make a correction on page 752, in view of the change in standard preservatives just approved. Under the heading "Preservative" and opposite the word "Creosote" delete "classes one, two and three." In other words, it will read:

The preservative used shall conform to one of the following standards of this Association: Creosote, Creosote-Coal Tar Solution, Zinc Chloride.

I move the adoption of the Specifications for the Treatment of Air Seasoned Douglas Fir for publication in the Manual.

The President:—It has been moved and seconded that we adopt the Specifications for the Treatment of Air Seasoned Douglas Fir as shown on pages 750 to 754, inclusive. The motion is before you for discussion, but in order to amend or discuss these different items, I will ask the Chairman to read each one by its caption, and if there is any discussion please rise immediately and you will be recognized.

(Mr. R. S. Belcher read the headings of the specifications, beginning on page 750.)

The President:—Is there any discussion on this subject? Are you ready for the question? All those in favor will vote "aye"; contrary. It is carried and so ordered.

Chairman F. C. Shepherd:—The fifth report, Destruction by Termites and Possible Ways of Prevention, is shown under Appendix E on page 755.

We call attention to the fact that on page 713 there is a printer's error where it indicates Appendix D instead of Appendix E. This report will be rendered by Dr. von Schrenk, Chairman of the Sub-Committee.

Dr. Hermann von Schrenk (Consulting Timber Engineer):—This report is again in the nature of a progress report of research work dealing with insect destruction of timber structures. On the first page, page 755, we have given an account of the very

interesting set of experiments initiated last year by the R.C.A. Communications on Long Island.

The termites for some reason or other have been particularly active in the vicinity of New York this last year, and through the cooperation of Dr. Snyder of the U.S. Bureau of Entomology, a very large number of poles have been installed by the R.C.A. Communications to try out the effect of different soil poisons.

The second part of our report deals with the international exposure test under the auspices of the Federal officials. I call attention on page 759 to the fact that Fig. 2 was reversed, so that if you want to see what it should be you have to turn it upside down.

One of the important points which we call attention to this year is indicated at the bottom of page 759 and 760. It refers to the final report of the California Termite Investigations Committee. I am very sorry that the very large volume was not received in time so that we could have given a review commensurate with the significance of this report in our this year's Proceedings. We wish, however, to call attention to the fact that anybody interested in the activities of these insects—I may say again, as we did last year, they seem to be increasing—by all means should order this volume. It costs $5 and can be purchased as indicated on page 760 from the University of California Press, Berkeley, Cal.

The last part of our report deals with some additional notes on the wharf borer. Col. Atwood said that the marine borer is appearing in places where they have been free from it. The wharf borer, instead of attacking the marine structures from the water, is attacking marine structures from the air. If both the marine and the wharf borers keep on going you can see what is liable to happen to the untreated wharf structures. Very little is known of this insect as yet except as indicated in our last year's report, that it has been found on the Atlantic, Gulf, and the Pacific Coasts.

We are particularly anxious to have the members of the A.R.E.A. watch for its appearance, because if they carry out the same method of appearance that the marine borers and the termites have, we may be in for a rather serious attack almost any time. At any rate, it seems worth while to describe the insects and to suggest that a very careful watch be kept of their appearance, with the further request that the Committee be notified so that we may give it more detailed attention.

As stated, this report is submitted as information.

The President:—It will be so received. Are there any questions you would like to ask Dr. von Schrenk?

Chairman F. C. Shepherd:—The sixth report, Loss of Preservative in Treated Ties in Track Due to Use of Oil-Burning Weed Destroyers, is found on page 762 under Appendix F. This report is a continuation of investigations and studies with reference to loss of preservative in treated ties due to repeated use of oil-burning weed destroyers. Reports have already been presented in 1930 and 1932, and the Committee now submits a final report with the recommendation that it be accepted as information and the subject be discontinued.

The President:—The report will be so received and the question of discontinuance will be submitted to the Outline of Work Committee for action.

Mr. R. C. Bardwell (Chesapeake & Ohio):—In the President's Message to Committees, dated April 17, 1933, Subject (6) of Committee XVII—Wood Preservation, reads: "Loss of preservative in treated ties in track due to repeated use of oil-burning weed destroyers and effect of blowing off locomotives on line of road, collaborating with Committee XIII—Water Service, Committee XXII—Economics of Railway Labor and Committee XXVII—Maintenance of Way Work Equipment."

The report presented by this Committee in Appendix F appears to take care of the assignment regarding oil-burning weed destroyers but entirely neglects that part of the assignment concerning the effect of blowdowns of locomotives. We consider the effect of blowdowns of locomotives on treated ties to be an important subject. I know there has been considerable study made of this. I personally collaborated with Dr. von Schrenk. I do not think this subject should be discontinued, but it should be reassigned to the Committee and a report made in accordance with the assignment last year.

Chairman F. C. Shepherd:—We considered that those two assignments were separate subjects. We have not discontinued any action on the second subject but have done work on it. We did not feel that we had gone far enough to present a report on it. It is in our studies for the next year's report and will be continued. We thought that we would clean up this part of it because we had gone as far as we could go, and recommended that this information be accepted and the matter dropped in so far as the oil-burning machines were concerned.

The President:—The Chair asks that the Chairman of the Committee on Outline of Work take note of these remarks and take proper action.

Chairman F. C. Shepherd:—Methods of Protection of Treated Materials in the Field. This report is found on page 765, Appendix G.

Last year this Sub-Committee presented a tentative report for suggestions, criticism, additions, and now presents this year a final report with the recommendation that it be received as information and the subject be continued, with the recommendation to the Committee on Outline of Work that collaboration of Committee III—Ties, Committee VII—Wooden Bridges and Trestles, Committee XVII—Wood Preservation, be directed with Committee XII—Rules and Organization, to the end that approved rules be published in the Manual under the jurisdiction of Committee XII.

The President:—The report will be received as information, and the recommendation of the Committee will be given consideration by the Outline of Work Committee.

Chairman F. C. Shepherd:—Report (8), Service Test Records of Structural Timber Including Piling, will be found on page 770 under Appendix H.

In developing this subject, the Committee, through circular letters to various roads, obtained lists of a large number of bridges and trestles, and data related to the service life of same. As a result, the Committee now publishes four reports:

(1) Treated bridges that have given outstanding service.
(2) Treated bridges that have failed or have shown serious defects.
(3) Untreated bridges that have given outstanding service.
(4) Untreated bridges that have failed or shown serious defects.

On page 774 there is a correction. The word "Conclusions" should be dropped to below the next paragraph, so that the Conclusions will read as follows:

"Generally it is evident that creosoted timber trestles give prospect of life two or more times that secured from untreated timbers, unless the latter is of timber by nature resistive to decay, or it is in structures where service requirements and climatic effects are moderate or light.

"In creosoted timber structures that have shown early failures, the record shows them to have been caused by inadequate protection of surfaces exposed by field cutoffs, borings and destructive handling. Such defects limit the life of creosoted timber irrespective of its kind, whether pine, fir, cedar, oak or other timber of structural grade susceptible of treatment.

"Structures of untreated timber are generally not considered to be economic except where light service conditions, nearby supply and low costs prevail."

Your Committee now recommends that these conclusions be accepted for publication in the Manual, and that the remainder of the report be accepted as information and the subject be discontinued. I so move.

The President:—It has been moved and seconded to adopt and include in the Manual the three paragraphs under Conclusions on page 774. Is there any discussion? All those in favor will say "aye"; contrary. It is carried. The balance of the report will be received as information.

Chairman F. C. Shepherd:—That completes our report.

The President:—This Committee is to be congratulated on its fine work. We will now excuse them with the thanks of the Association (Applause).

DISCUSSION ON WATER SERVICE AND SANITATION

(For Report, see pp. 621–643)

Mr. R. C. Bardwell (Chesapeake & Ohio):—The report of Committee XIII—Water Service and Sanitation, is presented in Bulletin 362, pages 621 to 643, inclusive.

Before submitting this report, it is believed that it would be fitting for the Committee to announce that it sustained a severe loss during the past year through the death of one of its distinguished members, Dr. James H. Gibboney, Chief Chemist of the Norfolk & Western Railway. Dr. Gibboney was also Chairman of the Arrangements Committee at the time of his death. A memoir to Dr. Gibboney is presented on page 622.

Consideration has been given during the year to possible revision of the subject-matter in the Manual pertaining to Water Service and Sanitation, but the present set-up seems to be in very good shape. There are only a few suggested changes in view which are being studied, and recommendations will be presented next year.

The study on assignment (2), cause and extent of pitting and corrosion of locomotive boiler tubes and sheets, has been continued, and a progress report is given in Appendix A, to be presented by the Sub-Committee Chairman, Mr. J. H. Davidson.

Mr. J. H. Davidson (Missouri–Kansas–Texas):—The report on the cause and extent of pitting and corrosion of locomotive boiler tubes and sheets appears on pages 623 and 624 of Bulletin 362. The report is a brief review of progress made since the subject was assigned for study.

The outstanding method for inhibiting pitting and corrosion in locomotive boilers is to maintain the proper caustic alkalinity in the boiler water. References to previous reports are given for those who desire to study this subject in more detail.

The fact that boilers of stored locomotives may sustain serious damage by pitting and corrosion during storage periods makes it advisable for those responsible for providing suitable locomotive boiler feed water, to see that all concerned are informed regarding the possibility of such damage, to the end that it will be guarded against, and the quality of the feed water will not be unjustly held responsible for such damage. This report is offered as information.

The President:—It will be received as such. Are there any questions you wish to ask the Committee?

Chairman R. C. Bardwell:—The report on assignment (3), methods and value of water treatment with respect to estimating and summarizing possible savings effected, is given in Appendix B, and will be presented by the Sub-Committee Chairman, Mr. R. E. Coughlan.

Mr. R. E. Coughlan (Northwestern):—During the past year your Committee has endeavored to further summarize the monetary value of the various methods of water treatment.

It has been a physical impossibility to obtain definite records of any value from all of the larger railroads comparing the savings before and after definite water treatment programs have been instituted, because of the fact that prior to the installation of water treatment, many of the roads have no definite record of the damage done by unsuitable water over any length of time. We have found, however, that all of the roads which have a definite program installed are now showing a decided reduction in shop repair and material formerly purchased to replace that destroyed by unsuitable water.

This, together with the increased mileage between boiler washings, and the numerous government extensions on boiler flues over the four-year limit, which all of the larger railroads are now obtaining, clearly indicates that the monetary value is becoming a decided factor in reducing operating expenses. The report this year is offered as information.

The President:—It will be received as such. Are there any questions?

Chairman R. C. Bardwell:—The final report on assignment (4), developments in pipe joints, is presented in Appendix C. This subject has been given a very considerable amount of study under the very able direction of Mr. R. L. Holmes, and it is believed that the information shown is an important contribution of special interest to Engineers. The report will be presented by the Sub-Committee Chairman, Mr. R. L. Holmes.

Mr. R. L. Holmes (Texas & Pacific):—Sub-Committee report No. 4, developments in pipe joints, is found on page 625, Appendix C, of Bulletin 362.

The salient points of the report are the number of joints available, many of which have been thoroughly tested.

No doubt much difficulty was experienced with the screw joints prior to the adoption of the American standard, and a similar condition will exist in fire fighting equipment until the National Underwriters' Standard couplings are adopted.

Many of the mechanical joints for cast iron pipe have been tested and proven satisfactory.

Practically no changes have been made in the bell and spigot cast iron pipe joint since its first use.

Special mention of the use of cement as a joint filler will be found on pages 630 and 635 of this report and complete specifications covering the use of cement as a joint filler may be had by communicating with your Sub-Committee Chairman.

I move this report be accepted as information.

The President:—This report will be so received. Is there any discussion on it?

Chairman R. C. Bardwell:—The subject of mosquito control is of considerable importance to railroads operating through the southern section of the country. Mr. Van Hovenberg, Sanitary Engineer for the St. Louis and Southwestern Railroad, has prepared a report on this subject under assignment (5). In the absence of Mr. Van Hovenberg, the report will be presented by Mr. H. F. King.

Mr. H. F. King (Erie):—The paper on "Essentials of Mosquito Control" will be found on page 637 of Bulletin 362. It describes briefly the range of recent engineering work aimed at affording relief to human beings at work as well as at play, through control of pest mosquitoes and refers to the economics of these projects.

In connection with disease carrying mosquitoes, the paper refers to studies being made in connection with the long distance transporting of new varieties of mosquitoes over our borders by airplanes and to the protection of our borders from the admission of infected mosquitoes or of infected human beings, and to the methods in vogue for the protection of our own people. The effect of impounding water for power or other

purposes in connection with the introduction of disease carrying mosquitoes, and the steps taken by our several states to combat this is described. The effect of malaria on railroad operation is referred to with a summation of the interest taken by southern railroads in applying relief methods. This paper is offered as information.

The President:—This report will be received as such. Are there any questions?

Chairman R. C. Bardwell:—The Committee is still studying assignment (6) design and maintenance of track pans for locomotive water supply, and again we announce that we hope to have the final report next year.

The study on assignment (7), methods for analysis of chemicals used in water treatment, has been held up a little, awaiting report and conclusions of work by a similar committee of the American Waterworks Association on which your Committee is represented. We hope to have a further report on this subject next year.

Due to the unsettled conditions in the political field for the past year, there have been no new developments to report from either Federal or State authorities on regulations pertaining to railway sanitation. It is therefore recommended that that subject be continued.

Assignment (9), disinfectants, fumigants, and cleaning materials, is of importance to railroads, as a considerable expenditure is made annually for such materials, and the information available for protection of the purchaser is limited. The progress report on this assignment will be presented by the Sub-Committee Chairman, Mr. W. P. Hale.

Mr. W. P. Hale (Rock Island):—The report of the subject assigned to the Committee may be found on page 640 of Vol. 35.

The subject assigned to the Committee has been deemed of sufficient importance to warrant extended investigations, since the assignment covers a scope of varied materials of innumerable usages, and represents a considerable expenditure on the part of the various railways. For these reasons, the report for this year will consist of a general outline of the scope of the subject, a differentiation of the terms "disinfection", "fumigation" and "deodorization" and a digest of the more common compounds for the purpose required.

Some idea of the scope of the assigned subject may be obtained from the following outline of correlated purposes for which disinfectants, fumigants, deodorants, and cleaning materials are used on railways, and on which detailed report will be prepared before conclusion of the assignment:

1. Disinfection and/or deodorization of passenger cars, cattle cars, cattle pens, poultry cars, cotton cars, copra and bone cars.
2. Fumigation of grain cars, grain elevators, camp cars, passenger equipment, hotels, eating houses, grain houses, etc.
3. Car cleaning, cuspidor cleaning, washing floors and woodwork and windows, drinking water disinfection, sterilizing water tubs, cisterns or tanks.
4. Cleaning and deodorizing cars or buildings used in handling fish, milk and cream, dressed and live poultry, etc.

All these matters are pertinent to the assigned subject "Disinfectants, Fumigants, and Cleaning Materials," and will be discussed in future reports.

Considerable confusion exists between disinfectants and deodorants.

"Disinfection" means the destruction of the agents causing infection. An object is said to be "infected" when it is contaminated with disease-producing bacteria. It is "disinfected" by destroying these bacteria.

A deodorant is a substance which has the power to destroy or neutralize unpleasant odors, such as those arising from organic matter undergoing fermentation or putrefaction. Such substances must be carefully distinguished from disinfectants. Deodorants are not, necessarily, disinfectants and disinfectants do not necessarily have an odor

No confidence can be placed on disinfectants simply because they smell of chlorine or carbolic acid, or possess the color of permanganate. Deodorants destroy smells; disinfectants destroy germs. Many of the disinfecting agents are also deodorants, but all deodorizing substances are by no means disinfectants.

Fumigation consists of liberating fumes or gases with the object of destroying germs or vermin, insects, rats, mice, and other small animals, acting as carriers of infection, or destroyers of food products or other matter. Fumigation cannot take the place of disinfection. It is chiefly useful in preventing the spread of insect-borne diseases, and the destruction of damage to food and other products by rodents or insects.

In many instances certain types of fumigation are required by Federal statute. One instance is the required fumigation of cotton freight cars infected with Mexican pink bollworm, a very serious pest to cotton.

The first car fumigation houses for this purpose were built during 1919. At the present time there are six such houses along the Mexican border, with capacities ranging from 20 cars down. For several years liquid hydrocyanic acid has been used as a fumigant and satisfactory results have been obtained.

Another instance is the regulations promulgated by the Secretary of Agriculture, at present embodied in B.A.I. Order 309, under which the Bureau of Animal Industry is charged with the disinfection of premises and vehicles which may have become infected by diseased animals in the course of interstate transportation. This order specifically states as to when, where, and how cleaning and disinfecting of such cars, boats, yards and premises shall be done and lists the disinfectant.

Any complete report on the subject assigned must of necessity, to be of any value to the members of the Association, contain definite instructions concerning the use of the various materials, describe the particular compounds suitable for each particular purpose, and detail methods for their successful and economic use. This phase of the subject will be taken up in later reports.

Sub-Committee (9) asks that the material submitted be accepted as information and that the subject be continued another year.

The President:—It will be so received. Is there any question you would like to ask the Committee?

Mr. W. A. Radspinner (Chesapeake & Ohio):—The Southeastern Underwriters representative said there had come to his attention the fact that hydrocyanic acid gas resulted in poisoning in some cases. They took it up with the medical profession, and there was disagreement as to what the effect would be. Some of them contended that a man exposed to this gas, and who then did not go near it again for sometime, would not be affected. The other group claimed that if he was exposed to it he would retain the cyanid, and as soon as he accumulated enough of it it would kill him.

Mr. W. P. Hale:—My understanding of the use of the hydrocyanic gas is that if a person is affected by—or food products or other article are contaminated with—this gas during process of fumigation, the simple method of an hour's exposure in the outside air will eliminate any danger. Bedding which has been exposed for a period of seven or eight hours to the hydrocyanic gas can safely be slept on within an hour after fumigation in the open air.

Chairman R. C. Bardwell:—That concludes the report.

The President:—This Committee which is composed of experts in their particular line have again submitted some very valuable information. They will now be excused with the thanks of the Association (Applause).

DISCUSSION ON SIGNALS AND INTERLOCKING

(For Report, see pp. 333–341)

(Vice-President John E. Armstrong in the Chair.)

Mr. P. M. Gault (Missouri Pacific):—The report of Committee X is found on page 333 of Bulletin 360. The first subject the Committee has to report on is the developments of automatic train control. In the absence of the Sub-Committee Chairman, I will present the report. This report is presented as information.

I would call your attention to the roads listed at the top of page 334. The first list of roads have petitioned to discontinue the operation of automatic train control. The last two in the list, Alton, and Southern Pacific, are shown as "pending." The report was written last October. Since that time the Alton petition has been denied, and the Southern Pacific petition has been granted.

In the next list of roads that petitioned to discontinue operation of automatic train control and operate by cab signals in conjunction with wayside signals, the Boston and Maine petition is shown as "pending." That petition has been granted with the understanding that they will operate with cab indicators rather than cab signals, the cab indicators being used to indicate the position of the wayside signals.

I see Mr. Mills of the Bureau of Safety in the room, and if I have misstated either of these conditions I hope you will correct me. Am I right, Mr. Mills?

Mr. S. N. Mills (Bureau of Safety, Interstate Commerce Commission):—The cab indicator on the Boston and Maine calls attention to the fact of whether the wayside indication is clear or restrictive. The engineman is normally governed by the wayside indications. If the cab indication changes from clear to restrictive between wayside signal locations, he is required to stop and is then governed by the low speed restriction.

If the cab indication changes from restrictive to clear between wayside signal locations the engineman is permitted to resume authorized speed after proceeding a train length from the point where the change of indication occurred.

Chairman P. M. Gault:—Thank you, Mr. Mills.

This report refers to Exhibit A and Exhibit B. Exhibit A is found on page 339 and is the proposed standard aspects and indications for continuous automatic cab signals. These aspects and indications have been prepared by the Committee on Automatic Train Control of the A.R.A. and are being submitted to the various Divisions and Sections of the A.R.A. that are interested in this subject. For your information, they were approved by the Signal Section yesterday.

On page 340 is shown Exhibit B, which has the heading "Interstate Commerce Commission, Specifications and Requirements for Continuous Automatic Cab-Signal System." These are the specifications that were issued by the Interstate Commerce Commission to the roads to which they apply. They are shown here as information. They have not been formally approved by the Committee on Automatic Train Control of the A.R.A.

Unless there are some questions, that concludes the report on automatic train control.

Vice-President John E. Armstrong:—The report will be accepted as information.

Chairman P. M. Gault:—Mr. Post will handle the report on Appendix B.

Mr. W. M. Post (Pennsylvania):—This assignment is found on page 335. This Committee has presented several reports showing the savings and increased efficiency

secured in railway operation by signal indications in lieu of train orders and timetable superiorities. This is a final report on this assignment. The assignment for next year has been considerably broadened and will be, as I understand it, developments in railway signaling, which would include this assignment, but is broader.

The Committee presented reports in 1932 and 1933 on the economic results of centralized traffic control installations. In addition to definite money savings due to block and interlocking stations discontinued, and gross ton miles per train hour increased, there is an increase in the margin of safe operation, which results in intangible savings which cannot be definitely determined, but which are nevertheless real.

This report relates to intangible benefits and savings difficult to determine accurately, provided by a centralized traffic control installation.

You will note that the assignment at the head of this report reads as follows: "Increased efficiency secured in operation by signal indication, including remote control of switches, and centralized traffic control, in lieu of train orders and timetable superiorities." There has been considerable confusion as to just what "centralized traffic control system" is and what "remote control of switches" is, and what is the difference between them. At the meeting of the Signal Section yesterday definitions were approved, which I should like to read into the records of this Association.

"Centralized Traffic Control.—A term applied to a system of railway operation by means of which the movement of trains over routes and through blocks on a designated section of track or tracks is directed by signals controlled from a designated point, without requiring the use of train orders and without the superiority of trains.

"Remote Control.—A term applied to a system of operating outlying signal appliances from a designated point to facilitate the operation of trains over a designated section of track or tracks by means of signal indications, timetable and train orders."

You will note that the determining feature of centralized traffic control is that the signals give the authority for the train to move, and practically eliminates the need for the issuance of train orders.

You will note that under the heading "A Centralized Traffic Control System," we state regarding this system:

"1. Reduces number of written train orders.

"2. Reduces errors in the transmission of orders. Orders are transmitted by signals, which are surrounded by mechanical and electrical safeguards. If the control operator displays a signal not intended, protection against conflicting movements is automatically provided.

"3. Eliminates possibility of errors in interpretation or execution of written orders.

"4. Eliminates delays due to waiting for written train orders.

"6. Provides means so that disregard of stop signal indication can be instantly detected by the control operator. The knowledge that the control operator can, by observing the lights on the machine, detect any disregard of a stop signal tends to keep the engineman alert and thus reduces the chance that signals will be passed when displaying stop.

"8. Provides facilities for non-stop meets at passing sidings."

A report somewhat similar to this was presented by Committee I to the Signal Section yesterday, and in the discussion it was stated that a record kept of a certain centralized traffic control installation showed that 50 per cent of the meets were non-stop meets. This is no doubt due to the fact that after the enginemen have had experience running under the centralized traffic control system, they are likely to jockey their trains so that they will have a non-stop meet, that is, they will approach the siding slowly, possibly, so as to time it right, and run slowly through the siding, but it results in a large percentage of the meets being non-stop meets.

In No. 12 you will note we stated that it provides immediate information as to whether or not trains are losing time, and control operator is better able to plan the meets at passing sidings.

This is possible because in a centralized traffic control installation, the control operator has before him a number of light indicators which show him whether or not track sections are occupied.

No. 15 provides facilities for handling peak traffic conditions with no loss of efficiency.

No. 16 provides greater protection for the movement of motor cars and other equipment of the Maintenance of Way department, and control operator can protect their movements by signals when conditions require.

There are no doubt several other intangible benefits and increased efficiency supplied by a centralized traffic control installation. When a similar report was presented yesterday at the Signal Section meeting, in the discussion one of the members stated that a control operator noticed one night that there was something wrong with a certain track section, and he called the maintainer. The maintainer found a broken rail and called the section gang, and they repaired the broken rail without any delay to trains whatever. In another case a track circuit between the ends of a passing siding indicated there was something wrong, and trains were run around the trouble, through the siding, while repairs were being made to a broken rail.

That concludes this report, and it is presented as information.

Vice-President John E. Armstrong:—The report will be so received.

Chairman P. M. Gault:—Supplementing what Mr. Post said, I want to emphasize the fact that there is a difference between centralized traffic control and remote control. Centralized traffic control is a method of train operation, and remote control is a method of switch and signal operation. There is a good deal of confusion in regard to these subjects, especially when it comes to making up reports and classifications.

The next subject that the Committee has to report on is Synopsis of the Principal Current Activities of the Signal Section, A.R.A., Supplemented with List and References by Number of Adopted Specifications, Designs and Principles of Signaling Practice.

Mr. Stradling, who is the Chairman of this Sub-Committee, has been very ill and is unable to be present. I will present the report, which is found beginning on page 336. The first listed is Current Activities of the Signal Section, A.R.A.

Specifications revised.
Drawings revised.
Requisites revised.
New specifications.
New drawings.
Drawings to be removed from the Manual.
Specifications to be removed from Manual.
Requisites to be removed from Manual.
Recommendations to be removed from Manual.
Forms to be removed from Manual.

It is not necessary to read the details of all of these. They are offered as information.

Vice-President John E. Armstrong:—They will be so accepted.

Chairman P. M. Gault:—That concludes the report of the Committee.

Vice-President John E. Armstrong:—The Committee is excused with our thanks for their very excellent report (Applause).

DISCUSSION ON ELECTRICITY

(For Report, see pp. 343–345)

(Vice-President John E. Armstrong in the Chair.)

Mr. W. M. Vandersluis (Illinois Central):—The report of Committee XVIII—Electricity will be found on pages 343 to 345 inclusive of Bulletin 360. This is a synopsis of the current activities of the Electrical Section.

Your attention is called to the complete report as given in Bulletin 359, Vol. 35 of September, 1933. With reference to assignment (1), the Committee has no new adopted specifications, designs, principles and practices to submit. The summary as given in Bulletin 360 and the complete report as given in Bulletin 359 are presented as information. There are certain Sub-Committee reports which we believe are of particular interest to the members.

Sub-Committee (3), Power Supply. The immediate importance of the development of pre-cooling and air-conditioning of rolling stock, which requires servicing equipment along the right-of-way, is brought to your attention. The questionnaire stresses the importance of standardized voltage and brings out the fact that the majority of systems so far have installed 220 volt, three phase, 60 cycle supply for right-of-way servicing equipment.

The size of the receptacles and plugs required for air-conditioning are much larger than those required for pre-cooling. Standardization of types of plugs and receptacles for use in servicing equipment of the different railroads, in joint stations, is of the greatest importance and should be brought about as promptly as possible.

Under Sub-Committee (5), cooperation in miscellaneous regulations, we wish to call your attention to the negotiations with the Edison Electric Institute covering principles and practices for power wire crossings over railroads, which have been agreed upon. Tentative minimum specifications to accompany the principles and practices have been completed as to the preliminary draft and have been sent to the various members interested for comments.

Upon completion and approval of these specifications by both organizations, your Committee proposes to put up a revised specification covering power wire crossings over railroads to supersede the present specifications adopted in 1921 and now in the Manual.

The report of Sub-Committee (8), Electric Heating, will be presented by Mr. J. M. Trissal, Chairman.

Mr. J. M. Trissal (Illinois Central):—The report on electric heating covers the application of electricity to snow melters, water heaters and space heating, miscellaneous heating equipment, and welding.

In preparing the subject-matter, the Committee collaborated with Committee XXVII—Maintenance of Way Work Equipment on snow melters and electric welding equipment. The information given on electric snow melters covers all of the various types of installations in this country, about which information is available.

Table 1 gives information as to the number of heater units installed, switches equipped and wattage per switch, as well as number of hours of operation during the winter of 1932–33. Various weather conditions encountered and the efficiency of the various types of heaters cause a considerable difference in the installed capacity of the various installations. Detail wiring diagrams showing the methods of controlling snow melters from interlocking towers or other centralized points are included.

The use of electricity for heating water for bathing purposes in various railroad facilities is increasing rapidly, and the various methods which may be employed are discussed. A table is included which shows the capacity of heaters required to heat various amounts of water in a prescribed time.

A detailed description is given of a hot water space heating system installed by the Reading Company.

The use of electricity for babbitt welding pots, sand drying facilities, glue pots, baking ovens and crankcases of automobiles and motor cars, is discussed in a general way.

A glossary of terms used in electric welding as well as desirable characteristics for electric welding equipment are covered in detail, with no attempt being made to compare desirable characteristics with the characteristics available in commercial machines.

The report is submitted as information.

Vice-President John E. Armstrong:—It will be so accepted.

Chairman W. M. Vandersluis:—The work of Sub-Committee (9), application of motors, is, we believe, of particular interest. For the first time there is presented for your information a general classification of motors, their essential characteristics and their proper application for railroad use. This report should be of particular importance to railroad Engineers in order to check the proper application of existing motors and in the laying out of new work.

Sub-Committee (10), clearances for third-rail and overhead working conductors, has submitted a report which brings up to date the data regarding third rail clearances and overhead clearances on existing steam road electrifications.

Sub-Committee (16), application of corrosion-resisting materials to railroad electrical construction, will be submitted by the Chairman of the Sub-Committee, Mr. R. P. Winton.

Mr. R. P. Winton (Norfolk & Western):—We have completed the tests of samples in Cedar Hill enginehouse at New Haven. These tests consist of installing a great number of various materials in the smokejack in order to make an accelerated test of corrosion under extreme smoke conditions.

The chemical and physical properties of these samples are shown on page 108 in Bulletin 359. The loss of weight of these samples is shown in Table 2 on page 112 in Bulletin 359.

In general, the bronzes have given a very satisfactory performance. Some of the aluminum and phosphorus bronzes show considerable pitting and apparent loss of homogeneity near the surface. The aluminum samples, as will be noted from the photographs and tables, were not so satisfactory. In the ferrous group, carbon steels, commercial steel and ingot iron show relatively higher losses. The copper-bearing steels show slightly less loss, and malleable iron still less loss. Some of the chromium and chrome nickel steels show a loss of weight as low as some of the bronzes, but some of them show considerable local pitting.

The copper-nickel steel showed the lowest loss of any of the samples tested, but definite conclusions should be deferred until further tests of this alloy. For your information, this alloy referred to is a steel casting with the addition of Monel, which is a natural alloy of copper and nickel. Apparently this material shows great promise.

We are also carrying on service tests at Hemphill tunnel on the Norfolk and Western, which represent actual operating conditions in tunnels with steam locomotives. We are also conducting tests at Lambert's Point pier where a series of samples are placed over a yard switching track, exposed to the smoke of locomotives and also salt air.

We hope this spring to install another set of samples in the Hackensack Meadows near New York, where the fumes of various chemical factories, and smoke from locomotives have a very severe action on conductors in that neighborhood. We want to see which of the alloys is best suited for conductors in this locality.

This report is submitted as information.

Vice-President John E. Armstrong:—It will be so accepted.

Chairman W. M. Vandersluis:—That concludes the report of the Committee.

Vice-President John E. Armstrong:—The Committee is excused with the thanks of the Association for their fine work (Applause).

DISCUSSION ON WOODEN BRIDGES AND TRESTLES

(For Report, see pp. 997–1009)

(Vice-President John E. Armstrong in the Chair.)

Mr. H. Austill (Mobile & Ohio):—The report is found in Bulletin 364, page 997. It is largely a progress report.

Mr. Smith, the Chairman of the Sub-Committee on Revision of Manual, is absent, so I will report this series of proposed revisions.

In the 1929 Manual, page 458, under heading "Relative Merits of Open and Ballast Deck Timber Trestles," paragraph 2 now reads: "The principal advantages of the ballast deck trestle, when compared with the open deck type, are: Better protection against loss and damage and interruption to train service due to fire; superior track riding qualities; more satisfactory and safer appearance; greater serviceability, and better performance when subjected to overload; vastly less expensive to maintain."

The Committee recommends that the last line, reading "Vastly less expensive to maintain," be deleted, and I so move.

Vice-President John E. Armstrong:—You have heard the motion and the second. Is there any discussion?

Mr. B. R. Leffler (New York Central):—Why delete it? It is a fact or it is not a fact. Is the maintenance more economical or is it not?

Chairman H. Austill:—The Committee thought it was more economical, but not vastly so.

Mr. B. R. Leffler:—Perhaps "vastly" should be omitted, but I do not think we should omit the economics. If there are any merits, we ought to stand by them.

Vice-President John E. Armstrong:—Are there any further questions? Are you ready for the question?

Mr. H. M. Stout (Northern Pacific):—I move to amend the motion by eliminating the word "vastly".

Mr. B. R. Leffler:—I will second that motion.

Vice-President John E. Armstrong:—You have heard the amendment to the motion. The motion is that the words "Vastly less expensive to maintain" be deleted. The amendment is that only the word "vastly" be deleted. Is there any further discussion? Are you ready for the question? Those in favor signify by saying "aye"; opposed likewise. The amendment carried.

Chairman H. Austill:—In the 1929 Manual, page 458, the heading of the paragraph now reads: "Comparative Merits of Ballast Deck and Reinforced Concrete Trestles." The proposed amendment is to add the words "Creosoted Timber," making it read: "Comparative Merits of Creosoted Timber Ballast Deck and Reinforced Concrete Trestles."

Vice-President John E. Armstrong:—Is there any discussion on this? In order to expedite matters, we will discuss these items as we come to them and make a suitable motion at the finish to cover the lot. Is there any discussion on this change?

Mr. Theo. Doll (Santa Fe):—Is not the word "ballast" a noun instead of an adjective? I would suggest that we change it to "ballasted" deck so as to make it an adjective.

Vice-President John E. Armstrong:—The Committee accepts that.

Mr. I. L. Simmons (Rock Island):—Do I understand that these are to be reinforced ballasted deck concrete trestles? Concrete trestles are now being built without any ballast on them. I wonder if we had not better define what we mean. What does

the comparison take in? Does it consider that the concrete trestle is to be a ballasted deck?

Chairman H. Austill:—At the time this was adopted it was considered that a concrete trestle would be ballasted deck.

Mr. I. L. Simmons:—Should not there be a distinction made due to present practice?

Chairman H. Austill:—Would you suggest adding "ballasted deck" to the concrete also?

Mr. I. L. Simmons:—I would like to make a motion that "ballasted deck" be included, making it read: "Comparative Merits of Creosoted Timber Ballasted Deck and Reinforced Concrete Ballasted Deck Trestles."

Chairman H. Austill:—That is agreeable to the Committee.

Mr. J. C. Irwin (Boston & Albany):—I ask the question whether this is pertinent to what is in the Manual. We are trying to make a new heading. The question is, does the material in the Manual apply to untreated timber and creosoted timber as well? We have not before us the material in the Manual, and we are making a specific title on something that may have been entered in the Manual to include both treated and untreated timber at the time. While it is probably creosoted, I think it should explain that creosoted timber is what is referred to in this section of the Manual.

Chairman H. Austill:—That is the case. That is the reason for this proposed revision, to make the heading really fit what was adopted, is what the Committee had in mind at the time of the adoption.

Vice-President John E. Armstrong:—That revision is acceptable to the Committee.

Chairman H. Austill:—Page 458 of the 1929 Manual, paragraph 5, under the heading "Comparative Merits of Ballast Deck and Reinforced Concrete Trestles," the Committee recommends the deletion or removal of that paragraph, reading:

"(5) Notwithstanding the fact that the two materials are, with certain limitations, equally suitable for the construction of trestles, the use of concrete is more in accord with the theory of conservation of natural resources and industrial economy."

Vice-President John E. Armstrong:—Are there any comments?

Chairman H. Austill:—Page 461 of the 1929 Manual, we have a detail showing the use of lag screws, fastening of guard timber so as not to require the dapping of the guard timber. This was adopted before the standard plans which are also in the Manual, and it is therefore a duplication as this is shown on the standard plans. The Committee recommends that this sketch and plan be eliminated.

Vice-President John E. Armstrong:—Is there any discussion?

Chairman H. Austill:—Page 466 of the Manual, paragraph 13 reads:

"Caps shall be sized and brought to a uniform thickness and even bearing on piles or posts. The side with the most sap shall be placed downward."

The Committee recommends that this paragraph be eliminated.

Vice-President John E. Armstrong:—Is there any discussion, gentlemen?

Mr. B. R. Leffler:—I think that interferes with the paragraph as it now exists. In framing a timber structure, there is no more particular work than the framing of the caps and the stringers. If piles do not bear exactly on the under side of the caps, large crushing stresses ensue, with consequent deterioration of the under side of the cap. I think the original as it stands is first rate. I would not change it.

Chairman H. Austill:—The Committee felt that the first part of that paragraph was taken care of in other instructions, and primarily what they had in mind was the last sentence reading, "The side with the most sap shall be placed downward." From information available, after several years of study, the Committee felt that that was not proper construction.

For the benefit of the Association I will read a digest of replies to a circular that was addressed not to all railroads but to those that we thought we could get good information from. While many replies were the same, I have only listed here those that differ. The reason given for placing the sap down was less damage from fire when the timber ages. Practically everybody who favored that type of construction gave that reason. It was preferable to place the sapwood in such a way that the least proportion of sap would be in contact with the other members of the structure. With the sap up, it absorbs moisture and quickly starts decay. The reasons given for placing the sap up were: More natural position, and reduces checking; less accumulation of water entering timber through shakes and checks; better opportunity to inspect, trim, and reduce fire hazard; greater bearing resistance; more important to have full width of bearing on solid wood, on the under side than on the upper side, for a stringer or cap would tend to roll less with the flat bearing on the rounded surface than with the rounded bearing on the flat surface. If the cap were boxed heart, with pith nearer one face than another, it might have a check running from that face to the pith. If this face were placed up, it would allow the entrance and penetration of moisture, while if the sap face were up, it would be more likely to have several small checks than one large one. If the cap were side cut, it would check less and shiver up less with the sap side up.

Mr. B. R. Leffler:—I think the views on sap are all right for untreated timber, but I think the best practice in these days is to use treated timber. If that is the case, then the requirement pertaining to sap is useless. What I was after was to retain the better framing which required the caps to be framed so as to fit the tops of the piles. I think the Committee ought to enlighten the Association as to the practice of creosoting timber caps. The practice is extending; I think it is almost universal east of the Missouri River, perhaps not out in the Northwest. I think we ought to modify our recommendations to fit creosoted timber requirements.

Chairman H. Austill:—The Committee felt, from the best information we could get, that it made no difference in creosoted timber whether the sap were placed up or down, and the judgment of the man in the field should be taken as to how that particular timber should be turned.

Vice-President John E. Armstrong:—Is there any further discussion on this point?

Mr. B. R. Leffler:—I move that the question of cap framing be retained.

Vice-President John E. Armstrong:—What you have in mind is to omit at this time this proposed revision of the Manual, leave it as it is?

Mr. B. R. Leffler:—Yes, except that if the Committee has considered this question of sap location in view of treated timber, I am indifferent to it; I do not care which way the sap is put. But I think the framing should be retained. I make a motion to that effect.

Chairman H. Austill:—If Mr. Leffler will move to eliminate the last line instead of the entire paragraph, that would be agreeable to the Committee.

Mr. B. R. Leffler:—I will so move.

Vice-President John E. Armstrong:—Eliminate the words, "The side with the most sap shall be placed downward"?

Mr. B. R. Leffler:—Yes.

Vice-President John E. Armstrong:—Is there any further discussion? Those in favor will signify by the usual sign; opposed likewise. The motion is carried.

Chairman H. Austill:—Page 466, paragraph 19 of the 1929 Manual reads:

"Stringers shall be sized to a uniform depth at supports. The edges with the most sap shall be placed downward."

The Committee recommends the withdrawal of that entire paragraph. It will also be agreeable to the elimination of the last line instead of the entire paragraph.

Mr. B. R. Leffler:—Here again I contend for the retention of the first sentence and the elimination of the second. I think the stringers should be sized to uniform depth, and so on.

Vice-President John E. Armstrong:—The Committee has suggested that that be revised, Mr. Leffler, that the last line be omitted instead of the entire quotation. Is there any further discussion on this point?

Chairman H. Austill:—I move that with the previously adopted corrections and amendments, the proposed revisions of the Manual shown on page 998 be adopted.

Vice-President John E. Armstrong:—You have heard the motion and the second. Is there any discussion? Those in favor signify by the usual sign; opposed likewise. The motion is carried.

Chairman H. Austill:—Subject (2) Simplification of Grading Rules and Classification of Timber for Railway Uses. Mr. Hawley, the Chairman of the Sub-Committee, is absent. This is merely a progress report.

Subject (3) Overhead Wooden or Combination Wooden and Steel Highway Bridges will be presented by Mr. Hart, the Chairman of the Sub-Committee.

Mr. R. P. Hart (Missouri Pacific):—The report of Sub-Committee (3) will be found on page 999 of Bulletin 364. The main information presented this year for consideration is a table of sizes for piles to be used in highway overhead bridges. The Committee felt that the sizes provided in the 1929 Manual for piling for railway use were larger than necessary for highway bridges. This table is presented as information, with the thought that it may be recommended for inclusion in the Manual at a later date.

Vice-President John E. Armstrong:—The report will be so accepted.

Chairman H. Austill:—The remainder of this report is either progress or presented as information. There is nothing requiring the action of the Association. To expedite matters and save time, if it is agreeable, we will so report.

Vice-President John E. Armstrong:—Is this action acceptable? If so, the report will be accepted.

Chairman H. Austill:—I should like to call attention to two misprints. On page 1002, formula (8) should read "arc-tangent" instead of "tangent minus the parentheses." In formula (9) the line is left out between the L and the 2. It should be L over 2 minus 1.

$$(8)\ r_1 = \frac{WL}{2} - \left[\sqrt{2}\tan^{-1}\left(\frac{L}{\sqrt{2}}\right) - \frac{W}{L}\,2.3\log_{10}\left(\frac{2+L^2}{2}\right)\right]$$

Vice-President John E. Armstrong:—Gentlemen, this Committee is doing a large amount of work. The fact that they are only in position to report progress and make interim reports at the present time is an indication of the amount of work they have in hand which is progressing toward a conclusion.

The Committee is excused with the thanks of the Association (Applause).

DISCUSSION ON MASONRY

(For Report, see pp. 957–996)

Mr. Meyer Hirschthal (Delaware, Lackawanna & Western):—The Masonry Committee presents its report as printed in Bulletin 364, beginning on page 957. Unfortunately, there occurred a misprint in some of the matter to be printed in Appendix A, which misprint will be pointed out to you and correction made by the Chairman of the Sub-Committee when presenting his report.

The Masonry Committee reports this year on six items of its assignment, Subjects (2), (3), (5), (6), (7) and (8), contained in Appendices A, B, C, D, E and F, and presents progress reports on the other assignments.

This year Committee (1), Revision of Manual, has no report because of the fact that it is awaiting a decision of the Joint Committee on Specifications of Concrete and Reinforced Concrete, which has reached a point in its deliberations where certain definite recommendations will be made, which will be contained in our next year's report, and on certain items which pertain to concrete specifications for buildings, which will then be included with a report of the Committee on Revision of Manual.

The first subject we do report on this year is that of assignment (2), specifications and principles of design of plain and reinforced concrete, contained in Appendix A. This report will be made by the Sub-Committee Chairman, A. N. Laird.

Mr. A. N. Laird (Grand Trunk Western):—The report of Sub-Committee (2), Specifications and Principles of Design of Plain and Reinforced Concrete is contained in Bulletin 364, pages 958 to 967 inclusive.

The portion of the report commencing at the middle of page 963, headed "Design and Construction of Reinforced Concrete Arches (Continued)" is a continuation of a report of this Sub-Committee on Specifications for Reinforced Concrete Arches. This portion of the report is directly related to the first paragraph on page 958, and in the printing it became disarranged. That portion should precede the subject-matter on Reinforced Concrete Trestle Design.

The first portion of this report which is designated as Section 8, is a continuation of the design section of the specifications. The sections dealing with the details of design and with construction requirements follow as Part III and Part IV. There is one misprint on page 965, the third line of the last paragraph. The last expression should read: "At the approximate one-fourth points of the span." With this change this portion of the report is submitted as information.

The President:—It will be so received. Is there any discussion on it?

Mr. A. N. Laird:—The portion of the Sub-Committee report commencing on page 958 headed "Section 2" in small type, and entitled "Reinforced Concrete Trestle Design—E-60 Loading" should have been designated as Section 1, for clarity in connection with the recommendations of the Committee. This portion of the report, consisting of the group of figures indicated from 1 to 7 inclusive, is submitted after having been presented to the convention last year as information and is submitted by the Committee for adoption as standard practice and for publication in the Manual.

I so move.

The President:—It has been moved and seconded to adopt the designs as shown, Fig. 1 to 7 inclusive, as recommended practice, and for printing in the Manual. In order to permit discussion, I will ask the Chairman to refer to each of these figures and give the members a chance to rise and discuss the subject, if they so desire.

Mr. A. N. Laird:—The order in which these figures are presented is not quite the same order which the Committee wishes to recommend for actual publishing in the Manual, but for convenience in discussion I will adhere to the order that they appear in the Bulletin.

Fig. 1 on page 958 deals with the design for single bent construction.

Mr. B. R. Leffler (New York Central):—If this is a 5-pile bent construction, no provision is made for lateral bracing. Is it the intention to let the cap and the piles take care of that in a rigid frame?

Mr. A. N. Laird:—The size of piling indicated is 16 in. They are reinforced piles. In the design it was the intention to provide for normal heights of trestle only, and in the case of extremely high trestles, additional construction in the shape of collars, and so on, would be required.

Mr. C. C. Westfall (Illinois Central):—I was under the impression there was a design in the Manual now for 18-in. concrete piling. I wonder if this is intended as a change from the Manual.

Mr. A. N. Laird:—The pile that is indicated as Fig. 5 is a 16-in. pile. There is no pile 18 in. in diameter now in the Manual. This 16-in. pile is a part of a specific design.

The next one, Fig. 2, deals with double bent reinforced construction. It is for use in long trestles for longitudinal stiffness.

The President:—Is there any discussion on this design?

Mr. A. N. Laird:—Fig. 3 at the bottom of page 959 indicates the end bent construction which is similar to Fig. 1 but with a slight extension of the bent cap and with the addition of a ballast wall.

The President:—Is there any discussion on this figure?

Mr. A. N. Laird:—Fig. 4 deals with the design for the slab, indicated as 16 ft. long, center to center of bents.

Mr. B. R. Leffler:—I do not like the cantilever action of the cap. It is a wide cap on a comparatively narrow pile bed, and under deflection there might be considerable load thrown out on the corner of the cap. It seems to me the cap should have some transverse reinforcement with a sliver or diagonal piece. I refer to the bearing directly under the slab.

Mr. A. N. Laird:—May I call attention to the design of the bent cap itself in Fig. 1, also in Fig. 2 and Fig. 3, which indicates such reinforcement in the form of lateral ties extending around the longitudinal reinforcement. I also call attention to the fact that the top of the bent is chamfered slightly, which will throw the point of bearing very close to the end of the slab.

Mr. B. R. Leffler:—That is true. I withdraw my remarks.

Mr. A. N. Laird:—On page 961, Fig. 5 deals with the design of the concrete pile itself. This is for a precast unit.

The President:—Is there any discussion on this design?

Mr. C. C. Westfall:—Back to my other point. I do not see why, if the Association recommends an 18-in. pile, the 16-in. pile should be given as a sample for the design. The question might arise whether a change of 2 in. in the size of pile might change the details of the cap.

Mr. A. N. Laird:—The size of pile indicated is predicated on E-60 loading. It is felt by the Committee that the 18-in. pile for a 5-pile bent is not necessary for this loading. In case the loading were increased to E-65 or E-70, then there would probably be a change in either the number of piles or the size of piles to compensate for that additional loading.

Mr. C. C. Westfall:—Is it the intent to change the Manual and put the 16-in. pile in in place of the 18-in.?

Mr. A. N. Laird:—There is no 18-in. pile in the Manual.

Mr. C. C. Westfall:—The 18-in. pile was designed for E-60 loading. My point is the A.R.E.A. 18-in. pile is standard, as I remember, for E-60 loading. That 18-in. pile was put in the Manual to take the place of the 16-in. pile originally put in there.

The President:—Mr. Westfall, will you please give the reference to the pile in the Manual that you refer to? It is my understanding that it has been removed from the Manual.

Mr. C. C. Westfall:—I am sorry, but I do not have the Manual with me. It may be that that has been taken out of the Manual. I thought possibly the Chairman would correct me if I was wrong.

Chairman M. Hirschthal:—It is my impression that the 18-in. pile had been in the Manual but was withdrawn at one of the meetings here three or four years ago. That is my recollection of that topic.

The President:—I think that is correct.

Mr. J. E. Willoughby (Atlantic Coast Line):—The 16-in. piling is sufficient for any purpose which the Committee has considered. We have not found it always sufficient for the protection of the reinforcement. After a number of years of use of the 16-in. piling, we have abandoned it for the 18-in. piling merely to get reinforcement deeper and farther away from the surface of the pile.

Mr. B. R. Leffler:—I do not think the Committee ought to stick to the E-60 loading. If these diagrams were gotten up on the E-60 basis, I think it was a mistake. There are plenty of locomotives for these short panels, in particular, that are close to E-70. I do not like the idea of a recommended practice based on E-60 loading. That makes it too small if we are considering reinforced concrete as reasonably permanent.

Mr. A. N. Laird:—Mr. Leffler, the E-60 loading was adopted for this particular design because it was felt there were many locations where that loading would still be applicable and for direct comparison with the creosoted timber pile trestle of the same loading. It is the intention of the Committee to proceed with the preparation of similar designs for the heavier loading.

Mr. B. R. Leffler:—I noticed, however, that the Committee on Wooden Bridges and Trestles has given a tentative specification for E-70, and they have a table worked up for that loading.

Mr. A. N. Laird:—It is the intention to proceed at once to submit for the next convention tentative designs for the E-70 or E-72 loading. That point has not been definitely decided.

Fig. 6 deals with the details of trainmen's walks. There are alternate constructions indicated, both structural steel with timber plank, and reinforced precast concrete.

The President:—Is there any discussion on these designs?

Mr. A. N. Laird:—Fig. 7 on page 963 indicates the special construction where multiple track trestles are to be used.

The President:—Is there any discussion on Fig. 7? Are you ready for the question? The question is on the adoption as recommended practice and for printing in the Manual, of these seven designs. All those in favor will say "aye"; contrary. The motion is carried.

Chairman M. Hirschthal:—This subject, of course, will be continued.

The next item to be presented is assignment (3), Appendix B, Progress in the science and art of concrete manufacture, to be presented by Mr. L. W. Walter, Chairman.

Mr. L. W. Walter (Erie):—The report of Sub-Committee (3) is identified as Appendix B of the Masonry Committee's report and appears on pages 967 to 975.

Summarizing this report briefly, the first section deals with vibration in placement of concrete.

In the present state of the art, vibration may be defined as a method of assisting concrete into place by increasing its mobility through rapidly applied impulses.

Vibration as now practiced may be divided into five kinds as to method:

1. Vibration of forms.
2. Internal vibration.
3. Vibration of reinforcement, structural steel members, or track assemblies.
4. Platform vibration.
5. Unit vibration.

A short description of each method is given, as are also some of the advantages and disadvantages associated with their use, together with some precautions suggested. This is followed by an abbreviated bibliography on high-frequency vibration of concrete.

The second section of the report deals with ready mixed concrete, which is divided into two classes, namely, central mixed concrete and transit mixed concrete, differing as their names imply. The report lists some of the advantages and disadvantages associated with the manufacture and use of each. Your Committee would call particular attention to some of the precautions to be taken in their selection and use.

Reference is made in the report to the tentative specifications for ready mixed concrete, A.S.T.M. C-33T. Here I will state that a correction should be made in the second line on page 974. The serial designation should read C94-33T instead of C-33T.

The third section of the report deals with segregation of materials in concrete. These are classified as of three types, namely, segregation of materials in finely divided state or of low specific gravity; segregation of water and its incorporation in concrete in parts of structures in quantity in excess of that designed for the mix, and separation of mortar from coarse aggregates. A high degree of workability and stiff consistency are essential if segregation is to be minimized. The ways of securing both are described in the report. This report is presented as information only.

I move that it be received as such.

The President:—It will be so received. Is there any discussion on this report?

Chairman M. Hirschthal:—This subject is also to be continued.

The next assignment is (4), contact with Joint Committee on Standard Specifications for Concrete and Reinforced Concrete. My report is verbal. There has been a change in the representation of the A.R.E.A. on this Committee by virtue of the resignation of Mr. Richardson from the Masonry Committee, he being replaced by Mr. L. W. Walter as representative of the A.R.E.A.

The proceedings of this Committee have reached a point where, during the current year, we expect to have final specifications. Most of the assignments have been made to sub-committees of the Joint Committee, and these specifications will then be included in the Masonry Committee's report as revisions of the Manual or changes in the art, as the Committee will decide in its deliberations.

Subject (5) is foundations, and will be presented by Mr. D. B. Rush, Chairman of the Sub-Committee.

Mr. D. B. Rush (Robt. W. Hunt Company):—You will recall that we have worked on this subject several years. We first were instructed to draw up a specification covering the original research in the character of soil, and that work was published in Vol. 31, page 1176; next, we were asked to study a method of applying this research practically to the design of foundations. The results were published in Vol. 33,

page 650. Then we come finally to a general specification for the construction of foundations that could be referred to in writing detailed specifications for bridge structures, or could, in itself, be taken as a general specification. What we have written this year is not at this time for insertion in the Manual but for information. It is not intended to be a textbook. You know, there has been a good deal of criticism about some of the specifications in that respect. It is just supposed to contain the necessary general clauses that you gentlemen can well fill in with the details you desire, for the particular structure in hand.

The Committee, as I now remember it, was unanimous in the opinion that all three, or any one of the present sections of the specification must be applied by some one of you Bridge Engineers who are competent to do it. That does not mean by an inspector. That means by a man who is competent to do the investigating work, to design a structure and superintend the construction. Several new and, what we believe, interesting features have been inserted. Personally I cannot recall ever having seen before any definite recommendation of a competent body of men on any method of determining soil pressures. The Committee has gone on record as in general approval.

In the second place, I can remember no instance where any of the various methods of determining soil pressure have been approved by any body of men, and any method worked out for their application to design. In fact, they are generally so involved that only a very limited number of men would be able to use them.

At the very start of the general specification we made a change in the definition. The first two definitions are printed here and are presented for adoption and inclusion in the Manual. I should like to read those to you:

"FOUNDATION.—The natural material which supports the structure, and its loads, whether strengthened or not by the use of piles or other means to secure adequate bearing.

" 'SUBSTRUCTURE' refers to that part of the structure which supports the superstructure and its loads."

I might tell you in this connection that we had a definition of superstructure, but this only being a Sub-Committee on Foundations, that was left out. You will see that this makes quite a change in the ordinary, accepted idea. If you approve of it, we now move for its adoption and inclusion in the Manual.

The President:—It has been moved and seconded that these two definitions at the top of page 976 be adopted and printed in the Manual. It is not customary, as announced before, to discuss on the floor any particular features of definitions as may be termed in the nature of editing, but if there is anything materially wrong with these definitions, we would like to know it.

Mr. F. P. Turner (Norfolk & Western):—My conception of a foundation, as you described it, is the earth or rock that supports the entire substructure. That has always been described in textbooks which I have followed as the foundation-bed, not the foundation. The foundation is the material you place on top of the foundation-bed. This is a part of the substructure, and the neat work above is also a part of the substructure. I thought I would bring that to your attention.

Mr. D. B. Rush:—You are quite right. That is why I told you that this is a change. May I ask how you would differentiate between the foundation and the substructure?

Mr. F. P. Turner:—I think the foundation is really a part of the substructure; the neat work, which usually extends below the water level or below the ground, is another part of the substructure. That is my definition.

Mr. D. B. Rush:—We have made a change, and we want to know if you will adopt it. We believe that this is very much better.

Mr. F. P. Turner:—From my own personal point of view and understanding, I prefer the old definition, because it seems to me that you are describing something as a foundation which already existed, whereas you usually place the foundation as a part of the construction work.

Chairman M. Hirschthal:—It was just because of this type of misconception or misunderstanding or ambiguity that we decided to define foundation and substructure as we have. In the discussions of the Masonry Committee we found that various members understood a foundation your way and others understood it our way. We decided that once it is understood either way it will be generally understood that way. We therefore decided to define it as we do in the Bulletin and ask you to accept it that way so there may be a general understanding of the definition as it has been presented.

The President:—Are you ready for the question? All those in favor will say "aye"; contrary. The Chair is uncertain. I will have to ask for a division of the vote. All those in favor will please stand; those contrary-minded will stand. The vote is practically two-thirds in favor of the motion, only a majority is required. Therefore the motion is carried.

Chairman M. Hirschthal:—Just one more word. What Mr. Turner referred to as the foundation and neat work is generally referred to as a footing. That led to the misunderstanding. We decided not to differentiate between a footing and the rest of the substructure. That is how this definition arose.

Mr. D. B. Rush:—That is a method of determining whether or not you use piling in your foundation. The thing everybody wants to discuss is the classification of materials. They are all down here as we have classified them. Bear in mind that that is the classification of a committee of Bridge Engineers but not a committee of contractors or people who are disinterested. That is what the consensus of this Sub-Committee is. What we want you people to do, if you will, is to write us all of the objections you have, criticisms, or approval, or anything else, on our classification of materials and be assured that it will be taken up before the next meeting.

I do not believe there is any need to read over this entire proposition, but we want you to write us, and then we will start on the draft of the final section of these specifications covering the construction of the substructure.

The President:—The balance of the report will be received as information.

Chairman M. Hirschthal:—I regret very much that it was necessary to curtail the discussion on the subject of Foundations which we feel is a very, very important subject. I want to urge the members to send their comments, either adverse or favorable, criticisms and suggestions, to the Chairman of the Sub-Committee to aid him in collecting all this data in a revision of the specifications that have been drawn up thus far, if necessary.

The next subject is assignment (6), Appendix D, Tentative Specifications for Lining Railway Tunnels with Concrete. Mr. G. F. Eberly, Chairman of the Sub-Committee will present this report.

Mr. G. F. Eberly (Baltimore & Ohio):—The subject-matter of this report will be found on pages 979 to 983 inclusive, Bulletin 364. As you know, this subject is under the assignment, methods and practices of lining and relining tunnels.

This year we have prepared a tentative specification for lining railway tunnels with concrete, which is the beginning of a number of specifications for lining tunnels with

various materials. We also intend to determine the best material for the lining of railway tunnels for steam operation and for electrical operation.

Are there any questions on these tentative specifications? I will be very glad to answer them. If not, it is submitted as information.

The President:—It will be so received.

Mr. B. R. Leffler:—I would suggest that in Section 10 a statement be made to the effect that the 5.5 gallons of water covers any water that may be found in the aggregate. I think the Committee intends to have it so.

Mr. G. F. Eberly:—I think that is well stated, and we will make that correction.

Chairman M. Hirschthal:—This subject is also to be continued.

The next subject is that contained in Appendix E, (7) pneumatically projected concrete, to be presented by Mr. T. L. Condron, Chairman of the Sub-Committee.

Mr. T. L. Condron (Consulting Engineer):—The report of this Sub-Committee is found in the same Bulletin referred to, on page 984. The assignment of specification for pneumatically projected concrete has been covered by writing a tentative specification, and the word "Shotcrete" has been used as a brief descriptive form, not copyrighted, so that it could be readily used in specifications and on plans where it was desired to indicate the material to be used. The specification is presented for information. If there is anything you wish the Committee to add or any suggestions, we will be glad to have them.

Mr. B. R. Leffler:—I suggest that the Committee investigate the question of anchorage of the Shotcrete concrete on old concrete so as to be sure that the Shotcrete will be held to the old concrete. That is particularly important in ceiling work, overhead work, and the under side of arches. It is a question that has not been presented or discussed before any technical body that I know of.

Mr. T. L. Condron:—I think there are in the Manual paragraphs on that feature in connection with the repair of concrete structures. It would hardly seem necessary to repeat them in this specification.

Mr. B. R. Leffler:—That will take care of the matter.

Chairman M. Hirschthal:—This subject is also to be continued.

The next assignment is that contained in Appendix F, design of expansion joints involving masonry structures. Mr. C. A. Whipple, Chairman of the Sub-Committee, will present this report.

Mr. C. A. Whipple (Chesapeake & Ohio):—This report appears on page 986 in Bulletin 364. During the last two years the Committee collected from a number of carriers plans covering various types of joints involving masonry structures to meet various conditions. Last year it submitted sketches appearing under Appendix E, Bulletin 353, page 599, as information.

This year the Committee has made further study of the joints submitted, with criticisms and suggestions of the various details, and offers basic principles to be observed in determining the details of expansion joints, suggesting a classification of joints applying to both longitudinal and vertical expansion joints, with general discussion of the details.

Appearing on pages 987, 988 and 989 are comments covering the joints submitted. Sketches of the joints appear on pages 990, 991, 992, 993, 994, 995 and 996. It is recommended that the report be received as information and the subject be continued.

The President:—It will be so received.

Chairman M. Hirschthal:—Assignment (9) was for a review of the specifications for overhead highway bridges as prepared by the Association of State Highway Officials in order to discover some more rational means of design which will result in greater economy. Such review has been made during the year but it is not in such shape as to

be presented as a report, and the subject will be continued next year when we hope to give you a report.

That concludes the report of the Masonry Committee.

The President:—The Committee on Masonry has our thanks for their very excellent report, and they will now be excused (Applause).

DISCUSSION ON GRADE CROSSINGS

(For Report, see pp. 561–577)

Mr. J. G. Brennan (New York Central):—The report of Committee IX—Grade Crossings is shown in Bulletin 361, page 561. On the first assignment, Revision of Manual, including:

(a) Further study of the proper lighting of the base of signals where located in the center of highway, the Committee reports progress and recommends that the subject be continued.

(b) Further study and recommendation in regard to center-road installation of flashing light or wig-wag type of signals. The Committee reports progress and recommends that the subject be continued.

Appendix B, economic aspects of grade crossing protection in lieu of grade separation. It is the recommendation of the Committee that the subject be continued. Considerable work has been done on this assignment, but the Committee is not ready to submit a report.

Appendix C, recommend standard specifications for street crossings over railway tracks, both steam and electric. Mr. V. R. Walling, Chairman of the Sub-Committee, will present the report.

Mr. V. R. Walling (Chicago & Western Indiana):—This subject will be found in Bulletin 361, pages 562 to 568 inclusive, Appendix C, recommend specifications for highway crossings at grade over railway tracks, both steam and electric, collaborating with Committee I—Roadway, and with American Society of Municipal Engineers and American Transit Association.

This year four specifications are submitted for your consideration, namely:

(1) Specifications for preparation of track structure, width of crossing and approaches for construction of street crossings over railway tracks.

(2) Specifications for the construction of rail type street crossings.

(3) Specifications for the construction of wood plank street crossings.

(4) Specifications for the construction of highway crossings surfaced with oil processed gravel.

These have been submitted to the Roadway Committee, American Society of Municipal Engineers and American Transit Association, with whom your Committee has been instructed to collaborate, and no exceptions have been taken.

In this connection, there are three members of the Roadway Committee delegated to collaborate with this Committee. These members are likewise members of the Grade Crossings Committee, so that the contact is direct. We have had very many useful suggestions from them, which have been incorporated in the specifications.

As regards the collaboration with the American Transit Association, that is being carried on by your Sub-Committee Chairman with Mr. Archambault, who is Chairman of the Standing Committee of Ways and Structures of that Association. This is being carried on both personally and by correspondence, and is being satisfactorily handled.

We have also furnished the American Society of Municipal Engineers copies of all the data that we have prepared to date.

Your Committee is recommending the adoption as recommended practice and for publication in the Manual the first three specifications and submitting as information No. 4.

On page 563, specifications for preparation of track structure, width of crossing and approaches, for construction of street crossings over railway tracks—I move the adoption of this specification as recommended practice and for publication in the Manual.

The President:—You have heard the motion. Is there any discussion?

Mr. J. B. Jenkins (Baltimore & Ohio):—I should like to have an explanation as to just how the Committee will accomplish what is called for in the first sentence on page 564, and also the second sentence. In that connection I would like to call to mind the rule made by a single track road, prohibiting facing point switches, and also a law passed by a certain state that when two trains met at a grade crossing, neither should proceed until the other had cleared the crossing.

Mr. V. R. Walling:—I presume you refer, Mr. Jenkins, to the paragraph at the top of the page: "Rail shall be so placed that there will be no rail-joints within the crossing, and with joints preferably located not less than one-half rail length from the crossing."

Mr. J. B. Jenkins:—I should like to know how that is physically possible.

Mr. V. R. Walling:—It would depend to some extent, of course, upon the width of the crossing and the length of the rail. It seems to me that it would be perfectly feasible, for certain width crossings and certain lengths of rail, for that to be accomplished.

Mr. J. B. Jenkins:—Suppose you have a crossing 20 ft. wide and have a rail, say, 60 ft. long and do not have any joint within the crossing. One of the joints certainly must be less than half the rail length away from the crossing, probably both joints.

Mr. V. R. Walling:—It seems to me we qualify that by the second clause: "If, because of the width of the crossing, this is not practicable, the rail ends shall be welded to form continuous rail through the crossing."

Mr. J. B. Jenkins:—That would not accomplish it.

Mr. V. R. Walling:—May I have your suggestion?

Mr. J. B. Jenkins:—I would eliminate "and with joints preferably located not less than one-half rail length from the crossing." It is a physical impossibility to so locate them. I would eliminate the first half of the second sentence and substitute: "If the rail ends necessarily fall within the crossing, they shall be welded to form continuous rail through the crossing."

Mr. V. R. Walling:—We will accept that change, Mr. Jenkins.

The President:—The question then is on the motion to adopt this specification as recommended practice, with the change suggested by Col. Jenkins.

Mr. Meyer Hirschthal (Lackawanna):—I have just one little suggestion on paragraph 2. I am wondering whether it would not be preferable to simply say that proper drainage shall be provided at all crossings, cutting out the argumentative part. I do not think it is essential to put that into the specification. I suggest that paragraph 2 simply read: "Proper drainage shall be provided at all crossings." If you want to put in that it is a requisite, say "as it is a requisite," rather than putting the argumentative part first.

Mr. V. R. Walling:—We rather prefer it the way it is set up there, making a positive statement, of course, which is generally accepted, that a requisite for good track is proper drainage, and this shall be provided at all crossings.

Mr. Meyer Hirschthal:—I do not disagree with you that it is a requisite, but I do not believe that that part belongs in the specification.

Mr. V. R. Walling:—You want to have that read: "Proper drainage shall be provided at all crossings?"

Mr. Meyer Hirschthal:—Yes.

Mr. V. R. Walling:—We accept that.

The President:—Are you ready for the question to adopt the specifications with the two changes accepted by the Committee? All those in favor will say "aye"; contrary. It is carried.

Mr. V. R. Walling:—Page 564, (2) specifications for the construction of rail type street crossings—I move the adoption of this specification as recommended practice, to be published in the Manual.

The President:—It has been moved and seconded that we adopt this specification, (2), for the construction of rail type street crossings. Is there any discussion? All those in favor will vote "aye"; contrary. It is carried.

Mr. V. R. Walling:—Page 565, (3) specifications for the construction of wood plank street crossings—I move the adoption of this specification as recommended practice, to be published in the Manual.

The President:—It has been moved and seconded that we adopt specification (3). Is there any discussion?

Mr. J. C. Irwin (Boston & Albany):—On page 565, under materials and installation, it starts off with, "It is recommended that." Is that a necessary term in specifications? Could not you start the sentence with "Creosoted planking and shims", etc.?

In general, I would raise the question in a great deal of our work as to whether it should be approved for the Manual the first time it is presented. My experience has been that the Committee puts it up in what it considers the best form for action. It does not lose anything by seasoning for further discussion through another year. However, the Committee has recommended this. I would not raise a particular point on that except that I think we should all exercise a little caution in hurrying things through to the Manual if there has not been plenty of opportunity to read and study them. In this case my specific question is whether "it is recommended" is a suitable phrase for a specification.

Mr. V. R. Walling:—Our thought in that connection was this: We follow that up by stating "The accessibility of the various species of wood may determine the kind of timber and the kind of treatment, if any, that is most economical for use by an individual railway." Inasmuch as the railroads traverse such an enormous section of the country, in which many different kinds of wood are to be found, it may be that some road would desire to use a material not to be treated. We leave it open but recommend that creosoted planking shall be used. We do not make it mandatory. We prefer to leave it as it stands.

Mr. C. W. Baldridge (Santa Fe):—It seems to me that the Committee has one word wrong in the third from the last paragraph of this article, where it provides for planking the full length of the pavement, that is, a buffer plank between the railway crossing and the pavement. It seems to me that should read "the full *width* of the pavement" rather than "the full *length* of the pavement."

Mr. V. R. Walling:—I did not get that reference.

Mr. C. W. Baldridge:—On page 566, in the third paragraph from the bottom of this specification, it reads: "If pavement beyond the track is of concrete, a space of one inch shall be provided between the edge of planking and the pavement. If pavement is of construction other than concrete a 4 in. by 18 in. creosoted timber header shall be placed on edge the full length of the pavement", etc.

Mr. V. R. Walling:—You are right. That should be "width." We stand corrected.

The President:—Are you ready for the question? The question is on the adoption of specifications for the construction of wood plank street crossings. All those in favor will say "aye"; contrary. It is carried.

Mr. V. R. Walling:—Page 566, (4) specifications for the construction of highway

crossings surfaced with oil processed gravel. This specification is offered at this time as information.

The President:—It will be so received

Mr. V. R. Walling:—It is the recommendation of the Committee that this subject be continued for further study and the preparation of specifications for other types of street crossings.

Chairman J. G. Brennan:—The next subject is (4), relative economy of different types of highway grade crossings, Appendix D, page 568. Mr. F. D. Batchellor, Chairman of the Sub-Committee, will present the report.

Mr. F. D. Batchellor (Baltimore & Ohio):—This report is shown on pages 568 to 573 inclusive. On page 571 we have given suggestions for determining what type of crossing is the most economical for any particular crossing.

On page 573 in the summary statement the average life of concrete planks should be 17.5 years instead of 13.5 years. This report is offered as information.

The President:—Is there any discussion? The report will be received as information.

Chairman J. G. Brennan:—The next subject is (5), proper vertical curves on highways for grade separation projects. Mr. E. R. Lewis, Chairman of the Sub-Committee, will present the report.

Mr. E. R. Lewis (Michigan Central):—The report appears in Appendix E on pages 573, 574 and 575. The tendency of present practice of highways is to treat the sag curve in terms of the vision curve at the top of the grade. The Sub-Committee received very helpful response from the highway authorities of every state in the Union and all the various provinces of Canada to requests for details of present practice. The sag curve, especially, seems to be too generously lengthened. It is recommended that depression or elevation of highways required for separation from railroad grades be effected with the minimum of vertical curvature required for safety and utility.

It is further recommended that the foregoing be approved and published in the Manual. I so move.

The President:—The motion is on the adoption and inclusion in the Manual of Appendix E. Is there any discussion? All those in favor will say "aye"; contrary. It is carried.

This motion is carried. The Chair, however, would recommend to the Committee on Manual that they give consideration to the form in which this report is presented. I believe it needs some editing.

Chairman J. G. Brennan:—Subject (6), investigate the use and report on the merits and economy of the "Stop-and-Go" type of signal with red and green illuminated aspects, as a protective device at highway-railway grade crossings, under usual conditions and special conditions. This report is shown on page 575 under Appendix F.

It is recommended that the following conclusion be approved and that the Joint Committee on Grade Crossing Protection, A.R.A., be notified of such conclusion.

" 'Stop-and-Go' signals should not be used for the protection of railroad-highway grade crossings where they are operated exclusively by the passage of trains, and their use should be confined to special locations where their observance can be enforced by police power."

I so move.

The President:—The motion is to adopt that conclusion. Are you ready for the question? All those in favor will say "aye"; contrary. It is carried.

Chairman J. G. Brennan:—That concludes the report of the Committee.

The President:—The subject of grade crossings and its various ramifications is one of the important problems before the railroads. This Committee has done very good work, and we extend our thanks, and they are now excused (Applause).

DISCUSSION ON RIVERS AND HARBORS

(For Report, see pp. 677–697)

Mr. W. C. Swartout (Missouri Pacific):—Committee XXV—Rivers and Harbors is unique among the standing committees of the American Railway Engineering Association in that it consists of two separate and distinct committees, each having its special work and functions to perform, the Committee on Rivers and Harbors, and the Special Committee on Engineering Research, Inland Waterways and Intercoastal Canals.

The Committee on Rivers and Harbors is a scientific engineering research committee like the other committees of the Association.

The Special Committee on Engineering Research, Inland Waterways and Intercoastal Canals is for the purpose of studying the growth of the closer relationship between waterways and railways which we have witnessed during the recent years and perhaps handling, with public authorities, situations which may come up affecting these relationships. For the purpose of facilitating the work of this committee, the country is divided into nine zones, with a section of the committee for each zone, having its Chairman. These sectional committees, of course, handle questions peculiar to their zones.

The two committees are working and will work in close alliance on all waterways and related problems, according to a definite policy of correlation.

The report of Committee XXV will be found in Bulletin 363, page 677. We present reports on eight subjects and report progress on three subjects.

Sub-Committee (1), Revision of Manual, Mr. E. H. Roth, Norfolk and Western, Chairman. Mr. Roth is unable to be present, but, as a matter of information, we have gone over the Manual of 1929 and have found that it contains nothing that pertains to our Committee. There is, however, information in Supplements to the Manual as follows:

Bulletin 327, pages 92 to 95; Bulletin 337, pages 99 to 110; Bulletin 347, pages 75 to 83.

If on further study of these portions of the Manual, we find that revisions or suggestions are in order and should be made, appropriate recommendations will be made to the Association.

Subject (2), Definitions of Terms. The Committee this year presents thirty-one definitions of terms relating to Rivers and Harbors, as a matter of information, with the request that the members advise the Committee of any criticisms or comments. Your Committee has enlisted the cooperation of the Chief Engineer of the United States Army and of the similar branch of the Canadian government in the preparation of these definitions.

Possibly the most important definition presented this year is "Economic Justification." The definition as printed is not entirely satisfactory to the Sub-Committee and, of course, not to the General Committee. As this is a far-reaching definition and one fraught with possibilities of the utmost gravity, the Committee hopes that the membership will favor it with any comments they may have.

Appendix C, specifications for the construction of the several types of river bank protection in common use. This was prepared by the Committee of which Mr. P. J. McCarthy, of the Kansas City Southern, is the Chairman. The Committee is offering this specification for the information of the Association but we desire to retain jurisdiction over it because it requires editing and changes in several important respects. However, it is open to discussion if any of the members feel so disposed.

The President:—Is there any discussion on Appendix C? The Chairman of the Committee invites discussion.

Mr. F. L. Nicholson (Norfolk Southern):—I have carefully reviewed this specification, and it is one that goes into detail very minutely. It is a very valuable specification. It reflects considerable credit upon the Committee that prepared it. If the Committee had stopped at specifications covering materials and labor, I think they would have done a splendid work that could have been endorsed without much discussion. But it seems to me that they have gone beyond the bounds of specifications and have gotten into that of contract forms. Sections 1 to 3 and Sections 11 to 15 are not specifications.

We have a Committee on Contract Forms, which Committee recognizes always that there are times that a standard form will not apply and at times it is necessary to draw a special contract form. In order to meet such conditions, there has been provided coordination between the Committee on Contract Forms and the committee preparing specifications, in order that a form suitable for the special purpose may be prepared.

I should like very much, as this form is presented for discussion and for further consideration, to have the Committee take under advisement the omission of all of the paragraphs bearing on a construction contract. I make this point particularly because on yesterday we had a similar condition. In the report that was made by the Buildings Committee, they outlined five subjects for future handling, submitted to the organization for study and criticism. At the same time they submitted for approval and inclusion in the Manual a subject that was not in any of the Bulletins in the hands of the members but appeared in a Bulletin a year ago. I venture to say that not five per cent of the members who voted for inclusion in the Manual had the matter before them or had read it. What is there to prevent these five subjects that have now been submitted to us for study during the year, from being submitted in a similar manner at the next convention, and we will have no Bulletin before us from which to decide, but must act on faith alone?

My belief is that, in the consideration of any subjects for inclusion in the Manual, they should be in the hands of the members at the time they vote. I recognize that it was an economy measure, probably, that prompted its omission from the Bulletins in use today. In order that you may know that the objection now raised is justified, I want to refer you to page 540 of Bulletin 361. In the Specifications for Buildings for Railway Purposes, Steel Chimneys—Welded and Genuine Wrought Iron Chimneys, here is how the term "General" reads, which might mean much or little:

"The contractor shall completely design and shall furnish all labor, material, tools and equipment, and construct a steel chimney of the height and diameter shown on drawings and as specified. The chimney shall be either self-supporting, guyed or stayed as shown on drawings and as specified."

I question whether this organization desires to go on record with Manual matter that we shall require the contractor to design a chimney or any other structure. If such service is required, it is a matter for special contract and not for specifications nor should it be a recommended practice.

The President:—Mr. Nicholson, the Committee will consider your suggestion. You are discussing a matter that was up yesterday. Your point is well taken, and the Committee will take that matter into consideration.

Mr. J. C. Irwin (Boston & Albany):—In that connection in this immediate case, I talked with Mr. Swartout this afternoon and pointed out these difficulties. He had already agreed to take it under advisement. But as Chairman of the Committee on

Outline of Work, I should make it clear that specifications as defined in the Manual are that part of the contract describing the materials for the details of construction, and most of our committees have been able to confine themselves to that, leaving the agreement provisions with the Contract Committee.

I have been satisfied that Mr. Swartout, in this case, would correct that throughout the year.

Chairman W. C. Swartout:—Subject (5), types of bulkheads, jetties and seawalls, giving cross-section of each and stating the purpose which they serve, including comparisons of first cost, service life and maintenance cost of the various types. Mr. W. G. Brown is Chairman of the Sub-Committee and will present the report.

Mr. W. G. Brown (Florida East Coast):—A brief statement of Sub-Committee (5), which was assigned the study of types of bulkheads, jetties and seawalls, is shown under Appendix D on page 683 of Bulletin 363.

Much valuable data has been collected which, with additional data to be secured, we will study and assimilate into a comprehensive report this year. With this in view your Committee can now only report progress, with a request that the subject be continued.

The President:—The subject will be continued.

Chairman W. C. Swartout:—Subject (6), types of fender systems for protecting wharves and recommend suitable uses for each, including comparisons of first cost, service life and maintenance cost of the various types. Mr. Benjamin Elkind, of the Erie, is Chairman of the Sub-Committee and will present the report.

Mr. Benjamin Elkind (Erie):—The report of this Sub-Committee is on pages 683 to 688 of Bulletin 363. This report explains the purpose of the fenders and the three general types used—fixed, spring, and floating.

The report briefly describes the various kinds of fenders in use in different sections of the country and is illustrated by Fig. 1 to 7 on pages 685 and 686 of the Bulletin. The report covers only a part of the assignment and will be continued this year. The report is offered as information.

The President:—It will be received as such.

Chairman W. C. Swartout:—Subject (7), warehouse piers, coal and ore piers, car float piers and others, with recommendations as to the type suitable for use under varying conditions, including comparisons of first cost, service life and maintenance cost of the various types. Mr. R. C. Young, of the Lake Superior & Ishpeming Railroad, is Chairman of this Sub-Committee. He has been kept away from the convention by serious illness. Mr. Young, as you know, is one of the old warhorses of the Association and takes a lively interest in the Association and is assiduous in his work on committees.

In presenting his report, he sent me the following letter which I will read:

"On pages 688 and 689 is an account of the development of iron ore loading on the Great Lakes, with a brief general description of the modern iron ore loading docks now in use.

"At the bottom of page 689 and on page 691 is a description of the coal loading piers on the Atlantic Seaboard at and near Norfolk, Va., also grain elevators in the same vicinity.

"On page 690 is a table showing dimensions and capacities of the iron ore loading docks on the Great Lakes, which table is compiled and corrected each year by the Engineering Department of the Duluth, Missabe & Northern at Duluth.

"On page 692 is a brief general description of the coal and iron ore unloading docks and the crushed stone loading docks on the Great Lakes, followed by some comparative estimated construction and maintenance costs of timber, concrete and steel docks as of the year 1911, expressed in percentages.

"Near the top of page 693 is a brief description of coal and ore piers on the Pacific Coast.

"Your Committee has not attempted to show any sketches of designs but submit on page 693 a bibliography of the principal docks described above with greater particularity."

We submit this report as information, with a request that it be continued for further study and report.

The President:—It will be so considered.

Chairman W. C. Swartout:—That brings us down to Subject (10), economic principles involved in clearances over navigable waterways. Mr. R. H. Ford, of the Rock Island Lines, is Chairman of this Sub-Committee, and I will ask him to present the report of the Sub-Committee.

Mr. Robert H. Ford (Rock Island):—This is a progress report on what your Committee considers to be a fundamental principle of the economics of land transportation. To the end that an expression of the Association may be obtained for the guidance of our Committee, the following resolution is offered:

"*Resolved,* That this Association is in accord with the principles as set forth in this report of the Committee on Rivers and Harbors on economic principles involved in clearances over navigable waterways, and which in effect are:

"That proper clearances for navigable streams are those which will not unduly interfere with the operation of either land or water transportation, cause unwise expenditures to be made for physical readjustments, or place burdensome restrictions on their future expansion. There must be an economic balance in the interest of both forms of transportation."

I move the adoption of the resolution.

Mr. Albert Reichmann (American Bridge Company):—In view of the fact that the cost of all large bridges, whether built with public funds or by public utility corporations, must be borne by the public, I believe this resolution should be adopted and I therefore second the motion.

The President:—You understand that the procedure of action on these reports is laid down by the general rules. This is a little bit out of the ordinary, but, with the general consent of the convention, the Chair will entertain that motion. Do I hear any objections to it? All right, the motion is before you. Is there any further discussion? All those in favor will signify by the usual sign "aye"; contrary. It is carried.

Chairman W. C. Swartout:—Subject (11), cost to railways for construction, maintenance and operation of bridges over navigable waterways. Mr. F. E. Morrow, Chief Engineer of the Chicago & Western Indiana, is Chairman of this Sub-Committee. I will ask him to present the report of the Sub-Committee.

Mr. F. E. Morrow (Chicago & Western Indiana):—The subject of this report is cost to railways for construction, maintenance and operation of bridges over navigable waterways. This subject is different from most reports presented to the Association, in that it deals with the subject of what is considered an inequity in the present Federal statutes, and the determination of what is considered fair and equitable principles upon which our Federal statutes should be based.

No doubt all of the members of this Association are familiar with the fact that the obligation of constructing, maintaining and operating bridges over navigable waterways is now imposed almost entirely on the party or agency which makes the crossing over the waterway. Also, that all continuing obligations to make alterations and changes in such structures and the continued maintenance and operation of such bridges as altered or changed are likewise imposed upon the party or agency making the crossing over the waterway.

It is the view, as set forth in the report, that there are certain obligations which should rest, under certain conditions, upon the agency which provides and maintains the

waterways. Your Committee has arrived at the following conclusions as to principles which it believes to be equitable, and which should govern in providing funds for the construction and maintenance and operation of bridges, including approaches thereto, over navigable waterways:

"1. Any agency providing facilities for land transportation, when bridging a navigable waterway in its natural state, an improved waterway, or an artificial waterway, should assume the expense (but not more than) of constructing, maintaining and operating the bridge and other collateral facilities reasonably necessary to permit the use of such waterway in its condition at the time the crossing is made.

"2. Where an artificial waterway is constructed across existing land transportation routes, the governmental authority in charge of and providing the funds for the waterway project should bear the entire expense of constructing, maintaining, and operating bridges and other collateral facilities required on account of such crossing, not only as originally made, but all changes or alterations made thereafter on account of changes in the waterway or the character of traffic on such waterway.

"3. When a waterway is improved by widening, straightening, deepening or otherwise, or the character of traffic on the waterway is changed by improvements elsewhere, or by changes in the design of vessels using the waterway, or by changes in methods of waterway transportation, which require changes in the bridges or other collateral facilities carrying land transportation agencies over such waterway, the governmental authority in charge of and providing the funds for the waterway should bear the expense of making such changes in the bridges or other collateral facilities, and the additional expense of maintaining and operating such altered bridges or facilities over and above the expense of the maintenance and operation of the bridges and facilities as they existed before such changes were made.

"4. Any agency providing facilities for land transportation, crossing a navigable waterway, requiring, for its own purposes, changes in the bridges carrying it over the waterway, its collateral facilities, or in the waterway itself, the land transportation agency should bear the expense of making such changes, and the additional expense of maintaining and operating such altered bridges or facilities over and above the expense of the maintenance and operation of the bridges and facilities as they existed before such changes were made."

I wish to offer and move the adoption of this resolution:

"It is the sense of this Association that the principles set forth in the report of the Committee as to the allocation of the expense of the construction, maintenance and operation of bridges and other collateral facilities over navigable waterways are equitable."

The President:—This motion is also not strictly in accord with our general rules. However, the Committee wishes the expression of the convention on this subject, and the Chair will put the motion unless there is objection to it.

Mr. J. B. Jenkins (Baltimore & Ohio):—I am heartily in sympathy with the idea expressed, and I am glad the Committee used the word "should". It is a thing that ought to be done but, unfortunately, it cannot be done. No Congress can tie down any subsequent Congress as to expenditures. No Congress can make a contract by which the Government shall contribute certain amounts of money to maintenance, for example. The funds for maintenance must be appropriated by each individual Congress without respect to what any previous Congress has done.

The President:—Is there any further discussion? All those in favor of the motion will vote "aye"; contrary. It is carried.

Chairman W. C. Swartout:—That concludes the report of Committee XXV—Rivers and Harbors.

The President:—This Committee has done a vast amount of work, and they are to be complimented on their fine report. They are now excused with our thanks (Applause).

Mr. E. E. R. Tratman (Civil Engineer—by letter):—To supplement the report on protective fenders for piers and wharves, as given on page 683 of the 1934 Proceedings, it may be noted that a more elaborate system of hydraulic cushion fenders is used on the Verdon pier at the port of Bordeaux, France, which pier is used by large passenger steamers. These fenders are spaced about 100 ft. apart along the face of the pier. Each fender is about 20 ft. high and 33 ft. long, weighing 30 tons. It consists of a pair of vertical steel frames faced with horizontal timbers on the water side, and suspended from trunnion bearings just below the level of the floor or deck of the pier. Its outer face, or water side, is convex, and with the fender hanging free this face is inclined outward from the vertical, the fender being held in this position by means of counterweights on arms projecting from the rear of the fender frame. Connecting rods attached to the rear of the frame are attached also to the plungers of oil cylinders mounted below the deck and inclined slightly below the horizontal. Small pipes connect the cylinders with a larger oil main served by a pressure tank. The fender is not continuous, but a series of fenders is arranged at intervals along the face of the pier. The force or shock of a ship coming alongside is taken by the suspended fenders, which swing inwards, driving the plungers back into the cylinders and thus forcing the oil out through the small pipes and into the main. The passage of the oil through these small openings opposes or checks the movement of the fender. When the pressure against the fenders is released, as by the departure of the ship, the counterweights restore them to the normal position and the pressure in the oil tank then causes the oil to flow back into the cylinders as the plungers are withdrawn. In principle, the action is similar to that of the hydraulic buffers used in some of the large terminal stations on English railways, each buffer consisting of a pair of horizontal cylinders with piston rods ending in buffer heads which are struck by the buffers attached to the locomotives and cars of those railways.

DISCUSSION ON IRON AND STEEL STRUCTURES

(For Report, see pp. 1011–1064)

Mr. A. R. Wilson (Pennsylvania):—The report of this Committee is found in Bulletin 364, starting on page 1011. We present herewith report covering the following subjects:

Revision of Manual, found in Appendix B; tests of steel columns and formulae for design; use of alloy steels for structural purposes; impact—railway bridges, and bearing values of small rollers, found in Appendix A.

On the other subjects in our assignment, we report progress and have asked for their reassignment.

On the four subjects in Appendix A, tests of steel columns and formulae for design, use of alloy steels for structural purposes, impact—railway bridges, and bearing values of small rollers, the reports of these four Sub-Committees are included in the Specifications for Steel Railway Bridges, Appendix B.

Appendix B, Revision of Manual, Specifications for Steel Railway Bridges, for fixed spans not exceeding 400 feet in length. This specification has been entirely rewritten and revised and is issued as First Edition—March, 1934. The first specification prepared by this Committee for steel railway bridges was in 1903. Current revisions have been made, the last revision being in 1931.

I would call your attention to several major changes in this specification over the previous specifications: The recommended live load is E-72. On the new formulae for impact, the supporting data will be presented in a coming Bulletin of the Association.

The unit stress for carbon structural steel, the basic unit stress, has been raised to 18,000 lb. per sq. in. Column formulae and materials—the materials, particularly the structural steel, are in accordance with A.S.T.M. Specifications A-7-33 Tentative. These specifications for material have been adopted after close cooperation with the corresponding committee of the American Society for Testing Materials. I have been assured that at the coming convention of that society, which will occur in June, this new standard for structural steel, which is now tentative, will be advanced to standard.

In presenting this specification it is the desire of this Committee that we receive full, written criticism on the specification, and by that means the Committee hopes that it will be materially improved from that as presented. The Committee has appointed a special committee to handle such discussions and criticisms, so that in the coming meetings of our Committee they can be properly acted upon. As we are presenting this specification as information, this concludes our report.

The President:—This specification for steel bridges is a very important piece of work. We would like to have discussion on the subject, but as the Chairman has invited written discussion, I think that is the best way to handle it. It is submitted as information, but if there is any particular point that anyone wishes to raise at this time, we will be glad to hear it. Otherwise we will receive the report as information.

Mr. S. F. Grear (Illinois Central):—This is such a change from previous specifications, especially in its basic allowable stress, it seems to me it would be a little better if that were brought out on the floor here. What brings about such a decided change? Is it permissible to ask the Committee for that information?

Chairman A. R. Wilson:—The allowable unit stress is based on the material which we have specified which, if you will notice, the elastic limit has been raised, the ultimate strength now being 60,000 to 72,000. The old specification was 55,000 to 60,000. We feel justified in using the higher unit stress.

Mr. Meyer Hirschthal (Lackawanna):—There is just one point I should like to call attention to, in addition to the question of loading that was discussed earlier between ourselves, and that is the question of the "Loads received from two tracks," provision whereby for spans less than 175 ft. two tracks are considered for impact, whereas for a span over 175 ft. one track is considered.

I imagine that it would be preferable to have some sliding percentage or factor that would be applied rather than that abrupt change from, say 175 ft., to have two tracks, and for 176 ft., to have one track applied in the impact.

I am just making that suggestion for consideration, whether it would not be possible to have some factor applied rather than an abrupt change at some point.

Chairman A. R. Wilson:—We will take Mr. Hirschthal's suggestion into consideration.

The President:—Is there any further discussion?

Mr. Theo. Doll (Santa Fe):—In connection with the question of Mr. Hirschthal, I wish to make a suggestion. I hope I am not talking out of turn when I say I happen to know that the Committee has made some very important investigations, and one of them was an investigation of the loads that should be used on multiple track bridges. There are other investigations, also, that I do not want to mention, because I prefer to leave it up to the discretion of the Committee as to how far they want to follow my suggestion; but I think it would be an excellent thing if, when this new specification is submitted for adoption or preferably before it is submitted for adoption, the Committee would publish the results of some of these investigations. Some of them are very valuable and very interesting and would be useful not only to railway Engineers but other Engineers as well. If the investigation concerning multiple track bridges was published, I have an idea that Mr. Hirschthal's question would be answered.

Chairman A. R. Wilson:—It is the Committee's intention, before asking for adoption of these specifications, to present the supporting data from which we have drawn our conclusions.

The President:—If there is no further discussion, this report will be received as information.

Chairman A. R. Wilson:—That concludes the report.

The President:—This Committee is relieved with the thanks of the Association for their very good work this year (Applause).

DISCUSSION ON ECONOMICS OF RAILWAY LOCATION

(For Report, see pp. 671–674)

(Vice-President Robert H. Ford in the Chair.)

Mr. F. R. Layng (Bessemer & Lake Erie):—The report will be found in Bulletin 363, page 671. The only subject on which the Committee reports this year is to give a definition of "Rise-and-Fall." The report starts with several definitions that are quoted from various authorities.

A study of these definitions reveals that different values may be obtained for the amount of "Rise-and-Fall". Where the termini of the section of road for which "Rise-and-Fall" is to be determined are at the same elevation, no confusion arises in computing it, the answer being the summation of vertical rises in the profile, as it is evident that for each foot of rise there will be a corresponding foot of fall. Where there is a difference of elevation between the termini of the section of line under consideration, confusion arises in the determination of the number of feet of "Rise-and-Fall", as it is evident that there will be a difference between the sum of the vertical rises and the sum of the vertical fall by the difference in elevation between the termini.

As traffic in practically all cases moves in both directions over the same grades, it seems sufficient for all practical purposes to compute "Rise-and-Fall" for a round trip over the section under consideration. Under this method the total rises and total falls become equal, and the "Rise-and-Fall" for the line is given by one-half the sum of the vertical ascents for a round trip. While the amount of "Rise-and-Fall" obtained from the computation of same for a round trip does not exactly fit the theory under which the effect of "Rise-and-Fall" on operating expenses is treated, no great error is incurred, and as the effect of "Rise-and-Fall" on operating costs is of minor importance, the errors inherent in this method will be of little consequence.

The main effect of "Rise-and-Fall" is in fuel and time. At the present time the Committee is not prepared to offer any method of determination of the effect of "Rise-and-Fall" on these items of operating expenses or to state whether or not other items of operating expenses are affected by same, and to what extent.

It is recommended that the following definition of "Rise-and-Fall" be adopted: "Rise-and-Fall" is the sum of vertical ascents in rising from a starting point or level to a summit and returning to same point or level, inclusive of all grades on the profile between any two points or termini. It is mathematically expressed by the formula—

$$\frac{\text{Sum of ascents in one direction} + \text{Sum of descents in same direction}}{2}$$

I move the adoption of this definition.

Vice-President Robert H. Ford:—You have heard the report of this Committee. It is their recommendation that this be adopted for inclusion in the Manual. Are there any questions? If not, all those in favor will signify by saying "aye"; contrary-minded. It is adopted for inclusion in the Manual.

That is all the Committee have to report. They are excused with the thanks of the convention (Applause).

Mr. J. L. Campbell (Past-President—by letter):—The Committee on Economics of Railway Location presents to the 1934 convention of the American Railway Engineering Association a report upon "Rise-and-Fall" wherein it recommends a definition of "Rise-and-Fall" based upon the common interpretation that one foot of "Rise-and-Fall" consists of a rise of one foot and a fall of one foot, but wisely points out that mere summation of such rise and fall under the definition cannot be used to find cost of rise and fall. The Committee also says that it is not prepared to present a method for finding such cost.

Some reasons why the statement of the Committee is true appear in consideration of the following Fig. 1.

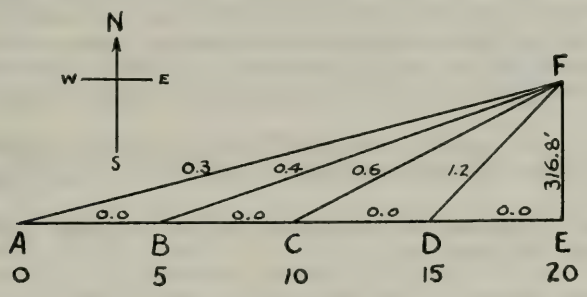

Fig. 1.

In Fig. 1, there are five grade lines, AF, ABF, ACF, ADF, AEF, each 20 miles long and rising 316.8 feet, the 0.3 grade line AF being assumed to be the grade of repose on which rolling resistance equals grade resistance, each being at the rate of 15.84 feet per mile, and said rolling resistance at 15.84 feet vertical per mile being constant for all grade lines. Then, in moving trains at uniform speed on the grade lines named, work done in terms of feet vertical would be as follows:

On AF	East 633.6—	West 316.8—	Total	950.4
" ABF	" 633.6—	" 396.0—	"	1029.6
" ACF	" 633.6—	" 475.2—	"	1108.8
" ADF	" 633.6—	" 554.4—	"	1188.0
" AEF	" 633.6—	" 633.6—	"	1267.2

The work done by the drivers and the brakes would be as follows:

	By Drivers		*By Brakes*	
On AF	East 633.6—	West 0.0	East 0.0—	West 0.0
" ABF	" 633.6—	" 79.2	" 0.0—	" 79.2
" ACF	" 633.6—	" 158.4	" 0.0—	" 158.4
" ADF	" 633.6—	" 237.6	" 0.0—	" 237.6
" AEF	" 633.6—	" 316.8	" 0.0—	" 316.8

In the first tabulation above, the work east is the sum of rolling resistance and grade rise resistance, each being equal to 316.8 feet vertical. The work west is the sum of the grade fall resistance, 316.8 feet vertical, and rolling resistance in feet vertical on the level part of the grade line.

In the second tabulation, the work east by the drivers is the same as the work east in the first tabulation, also done by the drivers. The work west by the drivers overcomes only rolling resistance on the level part of the grade line. The work west by the brakes is the difference in feet vertical between the fall of the inclined part of the grade line and rolling resistance on that part. There is no brake work east.

The difference in feet vertical between the fall of a grade line and rolling resistance thereon, when the first is greater than the second, is the only part of the fall which is effective in creating cost of rise and fall. Each grade line in Fig. 1 falls 316.8 feet. On each, effective fall, overcome by the brakes, and ineffective fall, overcome by rolling resistance, are as follows:

	Effective	*Ineffective*
On AF	0.0	316.8
" ABF	79.2	237.6
" ACF	158.4	158.4
" ADF	237.6	79.2
" AEF	316.8	0.0

Also, any rise of any profile grade against direction of train movement not in excess of allowable velocity head due to grade at the foot of such rise is ineffective.

Ineffectiveness of much of the rise and fall found on railway profiles is a reason why summation of total rise and fall computed by a composite unit composed of one foot of rise and one foot of fall is not a measure of or a basis for measuring cost of rise and fall.

Discovery or development of unit costs in items of operating expense due to rise and fall is a complex and difficult problem not yet solved. An opportunity is open to the Committee.

For fuller consideration of the problem, see the monograph by the writer in A.R.E.A. Bulletin 336, June, 1931.

DISCUSSION ON ECONOMICS OF RAILWAY OPERATION

(For Report, see pp. 879–922)

(Vice-President Robert H. Ford in the Chair.)

Mr. J. E. Teal (Chesapeake & Ohio):—The report of Committee on Economics of Railway Operation will be found on page 879 of Bulletin 364.

Your Committee reports progress on assignments 2, 4, 7 and 8.

Under assignment (1), Revision of Manual, including revision of the method for the determination of proper allowances for maintenance of way expenses due to increased use and increased investment, your Committee presents Appendix A, which will be found on page 880.

Since the subject-matter pertaining to maintenance of way expenses now appearing in the Manual on pages 1421 to 1432 inclusive was adopted in 1925, there have been changes in maintenance of way practices which have led to the suggestion that the "use-factors," that is, per cent affected by the use, conform to current practice.

It is generally understood that these figures were based on Class I railroad operating expenses applicable to the test period, 1913, 1914 and 1915, and are subject to adjustment when applied to individual carriers. As stated in the Manual on page 1430, "these percentages may be varied to suit the circumstances of each particular problem."

After carefully considering this question during the past few years, your Committee is of the opinion that there has not been sufficient change in maintenance of way practices or sufficient further information developed to warrant any changes, especially in view of the wording of the text quoted.

However, your Committee have found that this material has been used under conditions and for purposes contrary to the original intention, which has led to erroneous deductions; and therefore recommend that the following cautionary paragraph be in-

cluded in the Manual on page 1432, immediately below the first paragraph at the top of the page:

"Care should be exercised in selecting the period to be used as the base period for comparisons. The total equivalent gross ton miles in the base period should be the normal equivalent gross ton miles, that is, the normal use for which the property is maintained. The base period should extend over a sufficient period, with normal conditions, in order that the maintenance expenditures during the period will be normal. Comparisons of one year with another cannot be made under this method, unless the equivalent gross ton miles and maintenance expenditures for the year used as the base period are the normal equivalent gross ton miles and normal expenditures for the property."

I move that this addition be adopted and printed in the Manual.

Vice-President Robert H. Ford:—Is there any question or discussion? The Chair hears none. All those in favor of its acceptance will signify by saying "aye"; contrary-minded. It is carried. The section is adopted for inclusion in the Manual.

Chairman J. E. Teal:—The report under assignment (3), methods or formulae for the solution of special problems relating to more economical and efficient railway operation, will be found as Appendix B on page 880. This report relates to the economic effect of the 131-lb. RE rail section on the cost of operation as compared with the 130-lb. RE section.

The primary interest of this Committee in rail sections is that of the effect on the cost of operation. Without intent of trespassing on the assignments of other committees, we have, in our investigations, made use of an analytical method that has previously been presented to the Association in detail and which should, therefore, require little explanation. However, this method not only includes consideration of effect on train operating costs, but also those of the correlated subjects, maintenance of track and equipment. We have, accordingly, included those structures in our study as a matter of interest. The results shown by our analysis in this particular case indicate a distinct trend of improvement in the 131-lb. RE section as noted in our conclusion. The report is submitted as information, and I so move.

I might say that Mr. C.H.R. Howe is Chairman of this Sub-Committee and will be glad to answer any questions that may arise.

Vice-President Robert H. Ford:—Are there any questions?

Chairman J. E. Teal:—The report under assignment (5), methods for determining most economical train length, considering all factors entering into transportation costs, etc., appears on page 890. It is in two parts. The first part deals with locomotive capacities, and the second part deals with road and yard switching performances. Both have an important bearing upon the factors which affect transportation costs.

A theory in regard to steam locomotive capacities was developed last year for the purpose of determining the weight of train and the speed which would give the maximum gross ton miles per train hour. Other applications have been found where the method can be used as a short cut in preliminary estimates of locomotive performances, which is the reason for supplementing last year's report.

The text describes some of these applications, and others will suggest themselves when one becomes familiar with the uses of the chart on page 891 and the tables on pages 895 to 903.

The chart indicates the range covered by various classes of steam locomotives and offers a convenient way to estimate the horsepower capacity for the weight of the engine and the weight on drivers for the different types of locomotives.

Having determined the horsepower capacity of a locomotive, the tractive effort at

various speeds can be rapidly calculated by following the form on page 893 which is shorter than the method usually followed.

Part II of the report, beginning on page 904, is a preliminary introduction of two more factors which enter into the problem, for the purpose of attracting attention to the relation of yard switching performances and road performances. Analysis of these relations will be discussed in the Committee report next year.

The report is offered as information, and Mr. L. S. Rose is Chairman of the Sub-Committee. He and other members will be glad to answer any questions that may arise at this time.

Vice-President Robert H. Ford:—Are there any questions? The Chair hears none.

Chairman J. E. Teal:—The report under assignment (6), effect of volume of traffic on railway operating expenses, will be found as Appendix D on page 910. This is a large subject and very apropos. Your Committee has been giving considerable thought to this subject since its assignment in 1931 and now offers the first progress report. Mr. S. W. Fairweather, Chairman of the Sub-Committee, is unable to be present. However, if there are any questions, other members may be able to answer them. The report is offered as information.

Vice-President Robert H. Ford:—Are there any questions? The Chair hears none.

Chairman J. E. Teal:—That concludes our report. In connection with the last one I find a few typographical errors which will be straightened out with the Secretary.

Vice-President Robert H. Ford:—Gentlemen, you have heard the report of the Committee on Economics of Railway Operation. Are there any questions?

(Note.—Corrections referred to above are as follows: Page 913 middle of page: axis is $\bar{y} - y_a$ should read axis is $\bar{y} - \bar{y}_a$.

Page 916 first line following table: $z = .879 + 5.545$ should read $z = .879_x + 5.545$.

Also fourth line first paragraph: $z = .879 + 5.545$ should read $z = .879_x + 5.545$.)

Mr. Edwin F. Wendt (Consulting Engineer):—I do not have any question to ask but I rise to express my appreciation of the work of this Committee, not only during the past year but previous years. It seems to me that it would be difficult to assemble another group of men in this country who are so well informed on the subject of economics of railway operation.

The Committee has considered an especially difficult question during the past four years, during which time traffic has been on a rapid decline. You may remember that during the great panic of 1893, which lasted for six or seven years, the railroads lost 12 per cent of their gross earnings. There has been no other panic in the history of our American railroads, previous to the present time, when the railroads suffered so greatly.

When the depression of 1893 was concluded, the American Railway Engineering Association was formed. I am under the impression that it was that great period of depression which caused the founders of this organization to come together and to begin what has been the greatest work done in railway engineering during the past century.

Now, I should like the privilege of stating for the record a few facts which I think are most significant, particularly at this time when the severity of the depression (1929–1933) has been passed.

The Interstate Commerce Commission recently submitted to Congress its forty-seventh annual report in which it made some most significant statements, for example:

Freight revenue of Class I steam railways compared with the average revenue in the years 1927, 1928 and 1929, taken as 100 per cent, declined from 100 in the base period to 44.1 in March, 1933. There was a drop of 55.9 per cent compared with only 12 per cent in the great panic of 1893. While traffic in March, 1933, was the low point

in the past depression, it is a fact that the index of traffic stood at 45.6 in August, 1932. In other words, this low period of traffic extended over a period of almost nine months.

During the same period the average number of employees of Class I steam railways compared with the average number in 1927, 1928 and 1929, taken as 100 per cent, declined from 100 in the base period to 54.7 in May, 1933. This was the low point during the depression. You will notice that the decline in the number of employees was almost 10 per cent less than the decline in gross revenue. The index for employment in August, 1932, was 56.5, which was the lowest in that year.

We all know there has been fierce competition during the period of the depression, and I think it is significant that the Commission made a certain statement regarding the various forms of transportation. They observed:

"It is obviously not desirable to restrict this competition in so far as it is conducted on a fair basis. However, before such a condition of fair competition can be said to exist, it will be necessary that the various transport agencies pay the same rates for comparable skill, render reliable service on a non-discriminatory basis, and bear an equal tax burden."

The Commission also stated:

"As disclosed by the record" (general rate level investigation 1933) "the railroads have suffered from the depression as much as, if not more than, industry in general, the year 1932 and the first quarter of 1933 having been their worst periods in many decades."

The Commission also stated:

"A large part of the burden of maintaining an adequate transportation system was formerly borne by the high-grade commodities, but today much of this traffic either is lost to motor or water carriers or is handled at rail rates which produce little or no profit."

One thing more. During the past depression there were thousands of Engineers out of work. There are in this country 200,000 Engineers of all classifications. While there is no record of the number of unemployed, it certainly ran from 50,000 to 100,000. An Engineer told me yesterday that he had been in charge of certain engineering parties working in the Central West and that he was losing men. They were resigning to enter private industry. That is one of the best signs of the times.

Another good sign is the increase in activity of business, particularly railroad business, in the Pittsburgh territory. You know that Pittsburgh is one of the best barometers in the whole United States. The increase in business of the Pittsburgh territory in the month of February, 1933, over a similar period in 1932 was 35.8 per cent, and the increase in business in February, 1934, over January, 1934, was 10.4 per cent. These figures were compiled by the Bureau of Business Research, University of Pittsburgh, and are based upon production, iron and steel, electric power, coal, rail shipments and trade. They are reliable because the University receives its information from shippers and business people.

I make this statement because I think that we are now facing a much brighter future in which the railroads will regain a large part of the business which was lost, and as railroads prosper there will be much more work for the Engineer. It seems to me that that is something for which we can congratulate ourselves, because increased employment is much to be desired in behalf of the thousands of Engineers who have been out of employment during the depression.

Vice-President Robert H. Ford:—Mr. Teal, you and your Committee are excused. Gentlemen, that is among the best reports of the convention (Applause).

DISCUSSION ON ECONOMICS OF RAILWAY LABOR

(For Report, see pp. 645-662)

(Vice-President Robert H. Ford in the Chair.)

Mr. Lem Adams (Oxweld Railroad Service Company):—The report of Committee XXII—Economics of Railway Labor, will be found in Bulletin 362, page 645. While we have completed but three of the subjects assigned to us this year, the Sub-Committees have done a large amount of work on their subjects.

On Subject (1) the Committee have reviewed the Manual but do not find anything to report for change at this time.

Subject (2), analysis of operations of railways that have made marked progress in the reduction of labor required in maintenance of way work. We are not going to make a formal report on this subject this year as Mr. Parant, our Sub-Committee Chairman, is not here. The Committee went over the Lehigh Valley with Mr. G. A. Phillips, Chief Engineer, and looked over the railroad that we had made some very intensive studies of in our report a few years ago. We found conditions there very good. However, we do not know how to approach this subject at this time, as so many varying conditions have existed since we started this report. We wish only to report progress on that subject.

Subject (3), effects of recent developments in maintenance of way practices on gang organization. Mr. Schwinn, Chairman of this Sub-Committee, went into this subject very thoroughly and presented a report to the Committee. The report was very interesting and very thoroughly gotten up, but we have found so many variables that have come into track maintenance that we decided it was best not to present the report, not even as a progress report. We are asking that this subject be discontinued for a time, until we feel more certain of our grounds and whether or not the economies that we have made in force reduction during the past several years are economies that will be perpetuated.

Subject (4), methods of reducing work-train service and economies in maintenance expenses effected thereby. Mr. O'Rourke is Chairman of the Sub-Committee, and I will ask him to please present a brief report.

Mr. G. M. O'Rourke (Illinois Central):—The report is given in Appendix B, pages 646 to 652, inclusive, Bulletin 362. Expenditures made for work-train service on Class I railroads in the United States during the seventeen years ending 1932 are shown on page 646. On the opposite page the principal means of reducing work-train service are listed. On the following pages your Committee has gone into the details of many of the methods adopted to reduce this expense, finally reaching the conclusions presented on page 652. Those conclusions are:

"1. That maintenance of way operations should be carefully planned to reduce the number of work trains required.

"(a) By so programming the work as to permit it to be done in consecutive order and eliminate duplicate movements.

"(b) By utilizing spare time of light extra and local trains.

"(c) By having a thorough understanding by all concerned in the transportation and maintenance departments regarding work to be done and time required to do it.

"(d) By insuring that locomotives assigned have sufficient power to handle the work.

"(e) By loading materials in suitable cars.

"(f) By selection of the proper type of crane for unloading and loading rail and having a properly organized gang experienced in the kind of work being done.

"(g) By lining up work to be done in consecutive order to avoid backup movements and having sufficient work for a full day's work-train service.
"(h) By the extended use of motor cars to handle men and material.
"(i) By the use of other self-propelled equipment wherever suitable.
"(j) By further development and use of off-track equipment."

Your Committee recommends this report be accepted as information and the subject discontinued.

Vice-President Robert H. Ford:—The Committee recommends that this be received as information. Is there any objection? It will be so received.

Chairman Lem Adams:—Subject (5), programming of bridge and building work. Inasmuch as the subject-matter which the Sub-Committee Chairman will report is Manual material, we would appreciate your giving this very careful consideration. Mr. Botts will please present the report.

Mr. A. E. Botts (Chesapeake and Ohio):—The report of Sub-Committee (5), programming of bridge and building work, appears in Bulletin 362, pages 652 to 656, inclusive.

The object of this report is to provide a simple method whereby material and labor requirements for bridge and building maintenance can be accurately forecasted and the execution of the work programmed. This is accomplished by the use of three forms, namely:

Form 1, found on page 654, is used for recording material and labor required for each individual bridge or structure and is to be filled out at the time of field inspection. This information is furnished the general office and is the basis for the preparation of the program. Each project listed in the field is classified as to whether it is improvements to existing facilities or straight maintenance of a major or minor character by the use of letters "A", "B", and "C", as described in the report.

The actual programming of the work is accomplished by the use of Form 2, found on page 656. On this form are included estimated costs, accounting reference, and a careful scheduling of the work by months. This form may also be used as a progress report and a means of assembling final costs.

Form 3, annual bridge and structure force program, found on page 656, is for use by division officers for scheduling program by forces.

Your Committee recommends this report be adopted for inclusion in the Manual as recommended practice, and I so move.

Vice-President Robert H. Ford:—It is moved and seconded that the report as read be adopted and included in the Manual. Are you ready for the question? All those in favor will signify by saying "aye"; contrary-minded "no." It is a vote, and the report will be included in the Manual.

Chairman Lem Adams:—Subject (6), revised plans for outfit cars for maintenance of way department employees. This is a subject that has been before us for a number of years. While some of the plans which the Sub-Committee Chairman will present to you may be considered elaborate, there are a number of such outfits so equipped and in service on several railroads throughout the country today, and the Committee feels that these plans should be given your careful consideration. Mr. Magee will please present the report.

Mr. G. M. Magee (Kansas City Southern):—The report of the Sub-Committee assigned to prepare revised plans for outfit cars for maintenance of way department employees appears on pages 657 to 661 of Bulletin 362 as Appendix D.

Study was made of various types of outfit cars in use on different roads. From this study two series of plans were presented. One series provides for construction of outfit cars from retired passenger equipment, and the other from freight equipment.

In preparing these plans we have attempted to show a typical layout to accommodate workmen who are accustomed to a higher standard of living than is provided by early-day outfit cars. The individual roads may pattern in accordance with these general plans, with modification to suit the standard of living desired. Ten points of consideration are given, which should be borne in mind in making these modifications.

Your Committee recommends that this report be accepted as information, and the ten points of consideration on pages 657 and 658, together with the two series of outfit car plans be included in the Manual as recommended practice.

Mr. W. A. Radspinner (Chesapeake & Ohio):—These cars as they are shown only present a floor plan, but when they are put out on the road they are heated by ordinary stoves, or whatever happens to be standard on that railroad. The same kind of a smokejack would not be used on a camp car or ordinary box type, as on the passenger coach. When they get these cars out in cold weather they force the stoves, so that the first thing you know the whole thing is on fire.

I think that one of the points the Committee should consider is protection against fires of that kind. The range should be properly located and protected, and the smokejacks in these cars should meet with the requirements of the Fire Protection Association.

Vice-President Robert H. Ford:—Is there any other question or further discussion? If not, the motion is on its inclusion in the Manual.

All those in favor will signify by saying "aye"; contrary "no." It is a vote, and it will be included in the Manual.

Chairman Lem Adams:—There are two other subjects assigned to this Committee: (7) economics of methods of weed killing. Mr. Harsh is Chairman of this Sub-Committee. We have not done anything more on this subject other than to continue the study this year, but we hope in our next year's report to be able to give a final report on the subject; (8) gang organization and methods of performing maintenance of way work, including revision of time studies now in the Manual. Mr. Howe, who is Chairman of the Sub-Committee, is absent. However, he advises that very little progress has been made on the report this year, and we wish to continue the subject for further study.

That completes the report of the Committee.

Vice-President Robert H. Ford:—Mr. Adams, the convention congratulates you and your Committee on the excellent and painstaking work which is evident by this report. You and your Committee are excused with the thanks of the Association (Applause).

DISCUSSION ON STANDARDIZATION

(For Report, see pp. 1065–1077)

Mr. J. C. Irwin (Boston & Albany):—The report of this Committee is in Bulletin 364, page 1065. This Committee has nothing to present which has to be acted on by the convention, but it presents in concise form progress in standardization in matters mostly beyond the action of this Association.

Its first assignment is encourage the use of A.R.E.A. recommended practices and consider subjects for recommendation to the Board of Direction for sponsoring as projects for national standardization.

This Committee keeps in contact with the other standardization associations and carries such projects as seem to be suitable for national standardization beyond the field of the American Railway Engineering Association.

During the year the most important contact we have had was with the new organization of the Federal Coordinator of Transportation, Mr. Eastman, through his section of Purchases and Stores. On account of this Committee representing all committees, being composed of the Chairmen of all committees, the organization of the Federal Coordinator got in touch with this Committee very early, with the idea of finding out just what matters were in progress which might be shaped up to national standardization.

This contact with the Federal Coordinator of Transportation's staff, through Mr. Lockwood, Director of Purchases, and his assistants, Mr. Brown and Mr. Cooper, led to the general meeting in Chicago this fall, which was a combined meeting of this Committee with the General Committee of the Engineering Division and several of the Chairmen and Secretaries of other Divisions of the American Railway Association.

This meeting was arranged for the special purpose of giving Mr. Lockwood the opportunity of outlining to the A.R.E.A. organization the policies of the Federal Coordinator with reference to the use of recommended practices and, as far as possible, national standards.

This meeting in Chicago was really quite historic. President Wiltsee acted as Chairman of that joint portion which involved both the General Committee and the Committee on Standardization. It brought many matters into prominence, so that the Federal Coordinator's staff could see just where they stood and how to proceed with reference to A.R.E.A. practices.

Those things have been explained rather specifically in the reports of some of the other committees, notably the Committee on Rail and the Committee on Track. This is just a beginning and probably it is the greatest recognition that this Committee has had its part in extending the use of the A.R.E.A. recommended practices.

In regard to extending this use, the Committee again urges that the members of the Association try out the recommended practices as far as possible, if they are not already using them, and where they find any cases that do not fit their conditions, notify the Chairman of the Committee so that the matters can be taken up again and studied further, with the idea of eventually reaching uniform practices so far as possible.

Another assignment of this Committee is to maintain contact with standardization bodies and keep the Association informed on important matters developed by such contact. The report of this Committee consists of only eight pages, and those who have not read it I think will find it worth while to read it and find in condensed form the progress that has been made during the year on standardization matters.

The question of standardization of creosote has advanced today by approval of the A.R.E.A. Undoubtedly the joint action of the A.R.E.A., A.S.T.M., and A.W.P.A. will lead to a national standard on creosote.

The other subjects mentioned on page 1067 are under way, with a view to carrying them through to national standardization. I shall not take the time to go into them in detail, unless there is some question to be asked in regard to them.

New subjects have been presented at the meeting of the Standardization Committee, with a view to lining them up for action through the American Standards Association.

On page 1079 is a statement prepared by the Joint Committee on Grade Crossing Protection through Mr. Frank Ringer, its Chairman, with a view to presenting to the Association the status of progress in uniform grade crossing protection. On account of the short time we have, I shall not read these things in detail.

A

Page 1069 refers to our connection with the American Standards Association and its relation with the National Bureau of Standards. Both the American Railway Association and the National Bureau of Standards are member bodies of the American Standards Association, and they work together in that organization.

Last year Director Roper undertook to economize in the National Bureau of Standards by having the American Standards Association take over some of the simplified practice and standardization work that had been done previously by the Bureau of Standards, but no complete combination has yet been effected, although the tendency has been to throw more of the work over to the American Standards Association. The statement in regard to that situation is found on pages 1069, 1070 and 1071.

We incorporate a statement in regard to the status of standardization through the Canadian Engineering Standards Association, in which we have a large interest through our Canadian members. You will find that on pages 1071 and 1072. This statement was prepared by Mr. B. Stuart McKenzie as Secretary of the C.E.S.A. and covers Civil Engineering and Construction, Mechanical Engineering and Electrical Work.

This Committee has been making contact with the various standardizing bodies by meeting jointly with them and getting them to explain their methods, and letting them hear from us in regard to our methods and progress on standardization. As we reported before, in 1931 we met with the Bureau of Standards in Washington; in 1932 we met with the American Standards Association in New York, and this past year we had hoped to meet with the Canadian Engineering Standards Association, but the conditions in the United States prevented that at that particular time and made it advisable for us to meet with the representatives of the Federal Coordinator. We still have in mind our direct contact with the C.E.S.A. and are hoping to have a meeting there this spring which will enable us to form closer cooperation with that body than we have had heretofore.

On page 1073 you will find a list of the standards approved during the year by the American Standards Association, in which we have had a part, and a very interesting table which is now complete, on pages 1075 to 1077, showing the representatives of all Divisions of the American Railway Association that are taking an active part in the work of the sectional committees of the American Standards Association to produce national standards which are issued under the name of American Standards.

That completes the report of the Committee.

The President:—This Committee has been doing a lot of valuable work for the Association. They will now be excused with our thanks (Applause).

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